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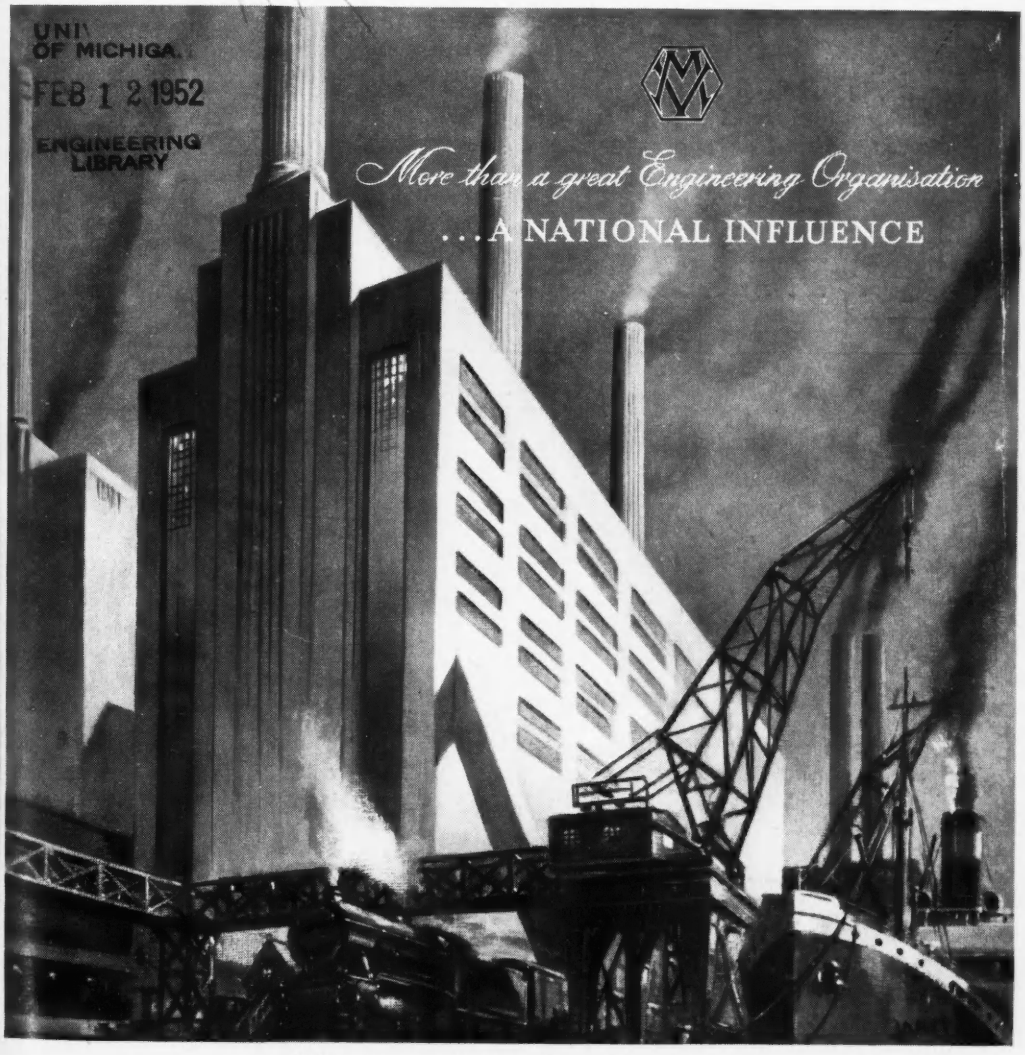

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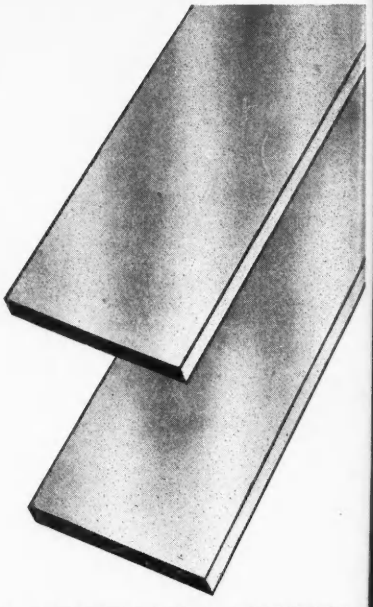

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *POLYAMIDE-CLAD WIRE ROPE*

It is claimed that application of a coating of polyamide plastic considerably improves the wearing properties of steel wire rope. In the industrial application of this process the polyamide is applied in a liquid state to the wire rope by means of a spraying process. After cooling down, the solidified polyamide coating encloses the wire rope in the form of a tight covering. It is also possible to cover individual wire rope strands with polyamide and to twist them subsequently into wire rope. The great advantage of polyamide-clad wire rope is claimed to be its long life, the polyamide itself being very resistant to wear so that the wire rope proper is less exposed to wear and tear. Moreover, owing to the application of the protective skin, the wire rope is protected against corrosion. The coating must, of course, be removed when splicing, and in this case a new coating must afterwards be provided. Polyamide is a good electrical insulator, which is of importance in applications where accidental contact of the rope with bare electrical conductors would otherwise have serious consequences. Polyamide-clad steel wire rope is claimed to be easily handled, as it is less subject to kinking and is smooth to the touch. Damage owing to the presence of projecting wires should therefore also be precluded. The manufacturers state that the new wire rope is more expensive than ordinary steel wire rope, but that it is cheaper than the stainless steel material. The new product would appear to be particularly suitable for cases where operating conditions are not unduly arduous and where corrosion is the main factor in determining service life.

● *TESTING ELECTRICAL SHEET*

The suitability of electrical sheet for transformer cores can now be quickly evaluated by the use of a newly developed instrument called the Integrating Pole Figure Goniometer. This device permits of rotating a specimen of the sheet in an X-ray beam in such a way that the arrangement of the small crystallites which make up the metal can be determined from measurements of the diffracted beam, by means of an X-ray spectro-goniometer. This method of evaluation utilises the fact that the arrangement of the crystallites in a metal, i.e., the preferred orientation or texture of the metal, influences many of its physical properties. From measurements of the preferred orientation of the transformer core material, the core losses and consequently the efficiency of the transformer can be accurately predicted. The new device possesses the advantage that these measurements can be made in approximately one-quarter of the time previously required. The instrument is also considered useful in obtaining fundamental information regarding crystallite arrangements in metals.

● *IMPROVED MAGNETIC AMPLIFIER*

The development of a parallel-connected magnetic amplifier has resulted in a considerable improvement in magnetic amplifier performance. The new circuit is stated to produce short response time, high gain, good linearity, wide output range and virtual independence of supply voltage. Time of response measurements showed that the output reaches the steady-state condition one-half cycle after application or removal of the control voltage. The small variation of the output current with fluctuations on the line voltage is exemplified by the fact that with a reduction in line voltage by fifty per cent, the output average current varies less than ten per cent. In this case the control voltage was set at a constant value to give one-fourth maximum output current. If the power absorbed in the control source is considered as the input power, and that absorbed in the load impedance as the output power, the gain of the amplifier may be established. On this basis it has been found that gains of more than 1,000 can be obtained at network frequency, and this with the use of commercially available component parts. But gains as high as 10,000 can be obtained by special means. This performance compares with a gain of the order of 20 to 50 obtainable with commercially available magnetic amplifiers of present-day design. This new development derives from recognition of the fact that the magnetic amplifier is a voltage-sensitive device, and not, as generally believed, a current-sensitive device, and control voltage is the only truly independent variable.

● *NESTED WELDING ELECTRODES*

A preliminary investigation of the use of nested electrodes for electric arc welding is reported to have produced highly encouraging results. The nested electrode consists of two or more filler metal rods, nested together but insulated

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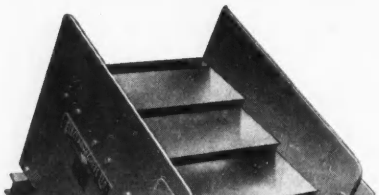

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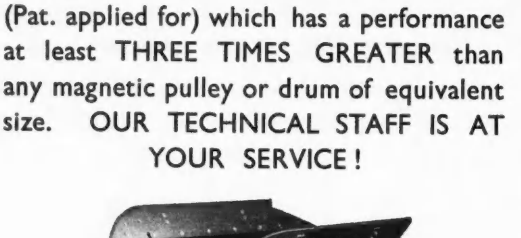

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from each other except at the end where they are gripped by the electrode holder and connected to a common source of current. The nested electrode offers parallel circuits for electric current flow. The welding arc will, however, occur only from one electrode rod until this is burned off sufficiently to bring one of the other, idling, electrodes near enough to the weld puddle for an arc to occur in the ionized atmosphere. The rapidity with which the arc switches from one rod to another may be controlled by the arc length and arc current setting. High amperage may be used, since each conductor has an arcing and a cooling period. The configuration of the nesting may be chosen to comply with specific welding requirements. Thus, a wide bead may be produced without "weaving." Owing to the short forceful arc produced, no trapped slag could be found by macroscopic examination, even when twelve electrodes were used in a nest. It appears that in manual welding on heavy plates, the welding cost could be reduced considerably by the use of nested electrodes. These electrodes not only allow rapid metal deposition in restricted space, but also make it possible to minimize the number of passes required to complete a weld. It is reported that with a nested electrode of appropriate contour, butt joints in $\frac{3}{8}$ in. plate have been completed with a single pass.

● *HIGH-IMPACT RESISTING PLASTICS*

It is reported from the U.S.A. that a new plastic material termed "high impact styrene" is now finding extensive use in the refrigeration industry. The enormous increase in the use of plastics in general which has taken place in the refrigeration industry may be gauged from the statement that today the average consumption of styrene per unit is no less than twenty pounds. And it is anticipated that with the introduction of high-impact styrene this consumption will further increase. Plans are now being prepared to use this material for large refrigerator parts such as door panels, one-piece liners, and miscellaneous large parts. Another very large field for the employment of high-impact styrene is said to lie in the manufacture of piping. Pipe produced from this material has been used for handling water and waste in farming, irrigation, drainage, lawn sprinklers, and cross-country systems. The excellent resistance of this type of material to acid and alkali conditions present in the soil is claimed greatly to contribute to its utility. Generally, it is expected that the development of new and large injection moulding equipment will greatly widen the range of application of plastic materials. Among new applications envisaged and expected to be realised in the near future are such diversified items as plumbing fixtures, bread boxes, and gun mountings. In the field of large parts, medicine and kitchen cabinets, as well as television cabinets, are mentioned. It is claimed that wherever plastics have replaced traditional materials of construction such as sheet steel, aluminium, nickel and hard rubber, plastics have provided a better article at lower cost.

● *RESISTORS OF SINTERED ALLOY*

In the construction of industrial electric furnaces, resistance heating elements in the shape of bars made of tungsten or molybdenum have been used. These elements make it possible to attain furnace operating temperatures above 1450° C. The employment of low operating voltage for heating elements of the bar type makes it possible to make the elements extremely robust so that no supporting means for the length of the element between the terminals is required. These tungsten and molybdenum elements are produced by powder-metallurgical methods. However, the electrical resistance of these heating elements at room temperature is so small that the normal operating voltage does not produce sufficient heating effect when starting up. Moreover, it was found that the operating current cannot be raised sufficiently without short-circuiting the transformer. In order to produce a material of higher electrical resistivity, a recent invention envisages the addition of a suitable oxide to the powdered tungsten or molybdenum. To prove suitable, such an oxide must have a melting point not below 1500° C and the amount of oxide to be added must not, of course, be so high as to make the material lose its metallic character. Satisfactory results were obtained with the sintering of a mixture of molybdenum and thirty per cent zirconium oxide. A bar of this mixture gave a specific cold resistance of 0·9 ohm per mm² per metre, which is substantially higher than that of pure molybdenum, amounting to 0·05 ohm per mm² per metre. At 1600° C, both materials show a resistivity ten times the aforementioned cold values.

● *NEW FILM THICKNESS COMPARATOR*

A new instrument for accurately measuring the thickness of thin films by means of colour comparison has been placed on the market. This film thickness comparator or "step gauge" consists of a film of barium stearate deposited in a series of successive monomolecular layers upon a plate of special glass. Each layer has a thickness of 0·1 micro-inch, and the successive layers are deposited in such a way as to build a series of steps which differ in thickness by one micro-inch. When the step gauge is illuminated by white light, each step reflects a colour, which is determined by the thickness of the step. The steps are thus seen as a series of coloured stripes on the glass plate, the colours being produced by the interference of light reflected from the front and back surfaces of the film. Since the colours are produced by interference rather than by selected

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absorption, they are not subject to fading. The step gauge serves as a standard of comparison with other films that reflect interference colours, i.e., those produced by evaporation, sputtering, plating, etc. It can also be used indirectly to measure vapour pressures and temper colours on metals, and may also be used for measuring the thickness of transparent conductive coatings on glass, as applied to aircraft windshields, etc. The measurement is simple and direct, the colour of the layer to be measured being matched with that of one of the steps of the gauge. The range of the new gauge extends from 2 to 16 micro-inches.

● *RATE-OF-FLOW BALANCE*

The measurement of large fluid flows in pipes is generally carried out by providing measuring orifices or Venturi tubes in the pipe itself and using appropriate equipment for measuring the pressure difference thus created. Devices have also been proposed in which the flow energy is balanced by electromagnetic means which are so constructed that the electric current established at a given instant is directly proportional to the rate of flow. A flow balance of this type may be installed in the immediate vicinity of the point of measurement so that only short connections are required. The electrical connection between the flow balance and the indicating, recording, or metering instrument is then made by electric wiring. A device of this type which has recently become commercially available is reported to contain no contacts or sealing liquids, or component parts which require supervision and servicing. It appears that the instrument is built for a wide range of rates of flow and can be supplied for pressures up to 1420 psi. Unfortunately, details regarding the actual construction of the instrument are not yet available.

● *MEASURING DECELERATION OF VEHICLES*

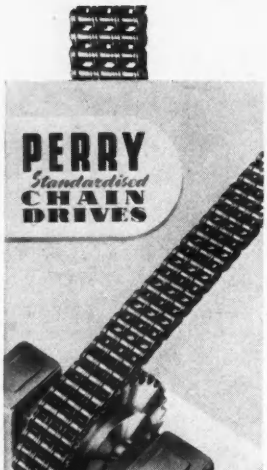
A brake tester has been placed on the market which, owing to its simplicity, lends itself to general use by drivers of motor cars and lorries, etc., to check proper working of the brakes of the vehicle. The design of this instrument is based on the forces of inertia exerted by a mass of mercury in a container, which displaces a coloured liquid in a suitably graduated indicator tube to which the container is connected. This " decelerometer " is a self-contained unit which is placed on the vehicle so that it is in view of the driver. A special type of decelerometer has been developed for the use on locomotives, but these instruments are designed for rates of deceleration smaller than encountered in automotive practice, and are capable of measuring very small rates as low as 13 ft/sec^2. The inertia principle can, of course, also be applied to the indication of rates of acceleration. As a rule, rates of acceleration are considerably smaller than those of deceleration, as the rate of acceleration is naturally limited by the propulsive power available. The sensitivity of accelerometers must, therefore, be made far greater than that of decelerometers, if a reasonable degree of accuracy of indication is to be attained. The instrument developed for the purpose is claimed to be capable of indicating rates of acceleration as small as 0·16 ft/sec^2, and provision is also made to indicate rates of deceleration of the same magnitude. For this purpose the instrument is furnished with two graduated indicator tubes, one showing rate of acceleration and the other rates of deceleration. These instruments are of small dimensions and are fully portable. They need not be affixed to the structure of the vehicle but can simply be placed upon the floor of the vehicle to be investigated.

● *GAUGE FOR MEASURING REDUCTION IN AREA IN TENSILE TESTING*

Conventional practice in the testing of ferrous metals for tensile strength consists in subjecting a specimen to a progressively increasing tension load and measuring the elongation resulting from various loads. From these data a stress-strain diagram can then be plotted, and graphic recorders have been developed which automatically draw such a chart. The diagram produced by such a recorder does not, however, take account of the reduction in cross-sectional area of the specimen caused by the elongation. A simple device has now been developed which measures and records the reduction in cross-sectional area of the specimen during the tension test. The essential feature of the apparatus is a fine wire or thread having one fixed end and one weighted end maintaining tension along the wire. An intermediate portion of the wire is wrapped around the specimen at a point where the most marked reduction in area can be expected. Adjacent to the testing machine is placed a recorder with a rotating drum for providing continuous records. A recording pen is mounted on a rack with teeth meshing those of a pinion on a shaft. This pinion has an integral pulley, around which the wire is wound one turn. It is evident that as the diameter of the specimen contracts with elongation, the length of wire around its circumference will decrease, thus imparting motion to the pinion and recording pen.

● *CORROSION PROOFING OF STEEL PARTS*

The resistance of machine components of steel to atmospheric corrosion, especially in tropical climates, while kept in storage prior to assembly, can be greatly improved by steam blueing the surface. The degree of protection that can be obtained by this treatment is indicated by the results of a comparative test in which electric motor parts treated by various methods were placed in a humidity cabinet. Tropical conditions



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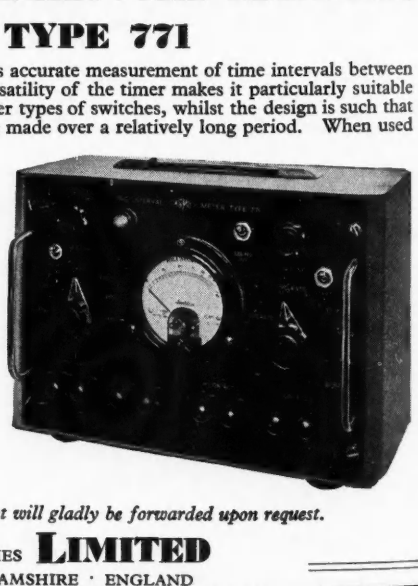

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were simulated by holding the pieces in an atmosphere of 100 per cent humidity and 110° F, and it was found that the steam-blued pieces withstood this atmosphere for three months, which was twice as long as the pieces treated by other methods. The latest process employed for steam-blueing consists in a steam treatment at 920° F. In this process the pieces to be treated are first placed in a normal-air atmosphere furnace, where they are preheated to 500° F and held at this temperature sufficiently long to ensure the burning off of any oil which may be present on the surface. Preheating also prevents the condensation of steam on the metal when placing the pieces in the steam oxidising furnace. In the latter the charge is first brought up to 700° F, at which temperature the furnace is purged with steam for 30 minutes to remove all traces of air. The temperature of the steam-filled furnace is then raised to 920° F and held at this temperature for one hour. The pieces are then removed from the furnace and allowed to cool in air.

● *REMOVAL OF GASES FROM VISCOUS LIQUIDS*

An interesting recent research report discusses the removal of gases dissolved in viscous liquids by purely mechanical means. While it is known that gases dissolved in liquids are slow to separate as long as the liquid remains in quiescent state, the oil-foam formation in bearings points to the presence of a contributory effect caused by shearing stresses in the fluid. It has now been found that a strong separating action by shearing effect in laminar flow also persists in the absence of the unequal pressure distribution as it exists in the oil film of a bearing. For this purpose an experimental apparatus was constructed, in which the liquid containing dissolved air was passed through a narrow annular gap of uniform width between two concentric cylinders, of which one was kept in rotation. The air could then be removed from the foaming liquid by means of an air pump. The influence of the laminar flow condition upon gas separation is explained by the investigator by convection effects and by the continual tearing and comminuting of existing gas bubbles, thus producing larger phase boundaries. As regards bearings, foam formation can be suppressed either by deaeration of the oil prior to its admission to the bearing or by keeping the bearing under pressure.

● *NEW BATTERY EMPLOYS RADIOACTIVE ENERGY*

The development of an "atomic" battery which utilises radio-active energy to produce electrical current has been announced. In this battery, radioactivity is converted directly into electrical energy by the use of a specially constructed cell having two electrodes of dissimilar materials surrounded by a gas. The cell is connected to a current measuring device and the gas is ionized by exposure to alpha, beta, gamma, or X-ray radiation. An electrical current is generated because of the difference in work function of the two electrodes. Positive ions formed in the gas are attracted to the noble electrode, and electrons similarly formed are attracted to the active electrode. The actual generation of electricity by the battery is described as a two-stage process, in which the first stage consists in converting radioactive energy into energy of ionization. Conversion of ionization energy into electrical energy constitutes the second phase. It will be appreciated that only a small current can be produced from such a battery. In order to obtain enough current to light a 100-watt light bulb, for example, a battery of this kind would have to be one cubic yard in size. The first application of the new atomic cell is in instruments for the precise measurement of gamma-ray activity.

● *PRESSURE OPERATION OF BLAST FURNACES*

A recently issued report on the status of the new method of operating blast furnaces under pressure reveals that all six of the large blast furnaces now under construction in the United States will operate under pressure and that five old furnaces are being converted to pressure operation in addition to eight now operating in the United States and one in England. On the basis of experience with furnaces now operating, it is estimated that these furnaces altogether would produce at least one million tons more pig iron each year than if operated conventionally. In operating a furnace under pressure, the exit-gas system is throttled so that pressure at the top of the furnace builds up; pressures up to about twelve pounds above normal atmospheric pressure are now used. With the system throttled down, the air blown in the bottom of the furnace moves through more slowly, so that it is possible to blow a greater weight of air through the furnace without blowing valuable ore out of the furnace. The availability of more air permits the burning of more coke per day and thus the smelting of more iron per day. The output of a particular furnace converted to pressure operation is given as 1600 tons per day as compared with 1400 tons expected under conventional operation. This production was achieved with a daily average of 6,340 tons of air blown into the furnace. In addition to increasing furnace output, pressure operation almost entirely eliminates the release of dust to the atmosphere.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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VOL. XIII. No. 1. JANUARY, 1952

Coal-Mining in the U.S.A.

THE success of the coal-mining industry in the United States is due in a large measure to the belief, shared by management and miners, that their respective ends will be served only by increased productivity at lower cost, and to the clear recognition by both sides of their respective rôles. This is the first broad conclusion of the 16-man Productivity Team from the British coal industry, which, under the auspices of The Anglo-American Council on Productivity and with E.C.A. technical aid, spent six weeks in the coalfields of the United States last year.

Although they only had time to visit 12 of the 9,000 coal-mines in the country, the members were favourably impressed with the general effectiveness of American mine management. They found a general acceptance throughout the American industry that modern mining is too complicated a business for one type of person to master in all its details, and requires specialist help. They studied the American success in welding management into a team, without weakening but rather with strengthening of the operational staff, and sum up the reasons for this as : General acceptance that all that matters is the final result ; the development of the service departments in response to the demands of the operational staff themselves ; the inclusion of the service staffs in the team ; collaboration " on the job " and not between offices, and identification of the individual with the achievements of the company. To achieve this end, American mine management makes wide use of budgets, forecasts and production standards. Management approaches its task in an orderly manner, working out, by objective study and analysis of operations, costs and conditions, the level of performance that can reasonably be expected for each unit, mine and section. Budgets and standards for management control are often built up from the foreman level.

American mine management recognises that administration is a matter of people, and in the selection of its officials attaches great importance to personal qualities. Sections are small (from 10 to 30 men) and the foreman's span narrower than that of his British counterpart. In the intimacy of the small team, morale seems to be high.

Under the day-wage rate system which predominates in the U.S. industry, productivity depends upon the time the machines are at work during the shift. The first duty of the section foreman is to think ahead and to plan the work of the crew so that the machines operate with the minimum of disturbance. Great stress is laid upon this duty of preventing hindrances to production rather than removing them after they have occurred.

The Team has several recommendations to make for management in this country. In particular, it says the British coal industry should give close attention to the systematic training of management to make use of modern techniques and aids, and to function as a team; it also should recognise that the success of mechanisation depends as much upon the proportion and quality of supervision as upon mechanical ingenuity. Above all, it urges that the British coal industry should inspire colliery management to initiate experiments and innovations and help them to do so. Many mining companies are now joining with the manufacturers of machinery to train operators and mechanics both at the factories and in the mines.

The Team had no doubt that the evolution of a national wage structure, based on day-wages and with relatively small differentials between the various grades, had made for happier labour relations within the American coal industry. It recommends that simplification of the national grade and wages structure should continue to be a major objective of the British industry and suggests that if full advantage is to be obtained from mechanical loading, the day-wage method of payment should receive close attention.

The Team formed the opinion that the average British miner and his family are at present better provided than miners in America in matters affecting their social well-being. They drew particular attention only to the energy with which the problem of rehabilitation is being tackled, and to the suggestion that doctors and scientists have an important contribution to make to the success of mechanised mining by helping to match the man and the job.

In comparing the technical differences between the coal industries of the two countries, the Team

(*Concluded on page* 30)

High-Temperature Arcs

By D. W. RUDORFF, M.Inst.F., F.R.S.A.

RECENT research reports show that important progress has been made of late in the technique of generating high-temperature arcs of the water-cooled type, this technique having been originally developed by H. Gerdien and A. Lotz some thirty years ago[1].

High-temperature arcs are obtained by producing a high current density in the arc channel by special means, and it is interesting to note that stable temperatures have been reached which exceed even the high temperatures momentarily prevailing in the electric spark. As J. M. Meek has pointed out in a recent paper,[2] higher current densities, voltage gradients, and ion densities exist in spark channels as compared with arc channels, so that in a spark channel in atmospheric air, the absolute gas temperature and pressure in the channel may be forty times higher than surrounding atmospheric values. This contrasts with a gas pressure of approximately one-twentieth atmosphere and an absolute gas temperature some twenty times the atmospheric values in the arc channel of the conventional type. These different characteristics are also reflected by the different current densities of the two phenomena, as, e.g., 29,000 A/cm² after 0·5 microsecond in the channel of a spark carrying 250 A, as compared with 500 A/cm² in a steady arc carrying 250 A.

Early attempts to increase the temperature of the electric arc, in order to increase its usefulness as an electric light source, had been based upon the assumption that this could be achieved simply by increasing the amperage carried. It was found, however, that higher currents raised the temperature of the cathode of the carbon arc from a normal level of 3,600° K to that of the anode, namely, 4,200° K, but the temperature of the latter could not be increased; nor did the light intensity per unit area of the arc increase. It became clear that higher temperatures could be achieved only by increasing the current density of the arc, and to achieve this it was evidently necessary to restrain the arc channel from increasing its area when passing increased amperage through it. A certain measure of success was achieved by O. Lummer,[3] who employed the artifice of operating the carbon arc in a compressed gas, the current density increasing with the gas pressure. This method did not, however, find much favour, probably because of practical difficulties in maintaining a stable arc in a compressed gas.

GERDIEN ARC.

Stimulated by certain earlier proposals, H. Gerdien and A. Lotz produced a device in which the arc channel is made to pass through a water-cooled bore in a copper plate, as indicated in Fig. 1. Here, water is introduced

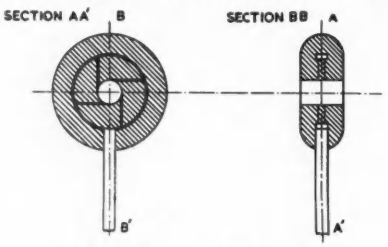

Fig. 1. **Original Gerdien orifice.**

under pressure into an annulus, from which it is tangentially passed into the bore by means of four holes. By introducing the water at sufficiently high pressure, the water is spread over the internal surface of the bore by centrifugal action, thus forming a cooling film, while the water escaping at the sides flares out and covers the side

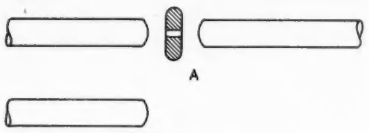

Fig. 2. **Arrangement of carbons with respect to Gerdien orifice.**

areas of the orifice plate. The latter can be arranged in respect to the carbons as shown in Fig. 2. This arrangement permits full unobstructed observation of the light emission from the bore of the orifice, and at the same time helps to stabilise the arc, owing to the magnetic blow, which prevents the arc from wandering away from the ends of the carbons. It was found that with orifice plates having bores of 5 mm diameter, currents of 800 A could be carried; and with a bore of 3 mm, 500 A could be passed continually. In the case of the 3 mm bore, the arc channel proper was estimated as 2 mm diameter, which corresponds to a current density of 10,000 A/cm². The voltage gradient of the part of the arc burning inside the bore was estimated as 40 volt/cm, and the specific power absorption as 200 kW/cm³. It is interesting to note that for a spark carrying 500 A, Meek[2] calculated the power input at a time of 1 microsec from breakdown as being about 1,000 kW/cm³, while for a spark carrying 300 A in air, Meek gives a voltage gradient of 142 V/cm at a time of 0·5 microsecond after breakdown; this falls to 36 V/cm at 8 microseconds. "The corresponding voltage gradient for an (ordinary) arc carrying the same current is about 2 V/cm."

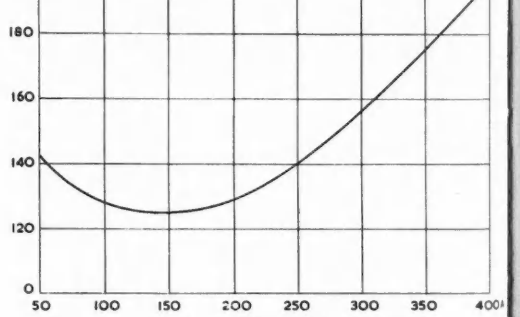

Fig. 3. **Arc characteristics.**

The rising characteristic of the high-temperature arc, as found by Gerdien and Lotz is shown in Fig. 3. The spectrum of the light emitted by the arc was found to show the hydrogen lines with an intensity never observed before in any other terrestrial source. With the use of a spectral photometer it was possible to compare the high-temperature arc with the cathode spot of an ordinary arc light carbon. This proved the light intensity of the hydrogen to be 20 to 50 times higher in the case of the

high-temperature arc. Experiments were also made to introduce other substances into the high temperature arc, such as Zn, Pb, Cd, Cu, Na, K, and C, which all produced spectral lines of greater intensities than those of hydrogen.

A subsequent research report on the high-temperature arc was published by Lotz in 1934[4], who pointed out that in view of the use of water as " insulating " medium in high-voltage circuit breakers, investigations into the characteristics of arcs submerged in water or oil had been made. These investigations had shown that in either medium the arc was surrounded by an atmosphere of practically pure hydrogen derived from the water or the hydrocarbons of the oil, as the case may be. In order to amplify the knowledge gained from the previous experiments referred to above, Lotz conducted further experiments with water-cooled arcs operating at voltages from 200 to 800 V and currents from 5 to 500 A, supplied by two 100-kW direct current generators. In order to minimise the danger of burning of the orifice because of insufficient water supply, orifices of sintered aluminium-oxide were used. A special method for starting the arc was also developed. This consisted in connecting the two carbon electrodes by a metal wire, the evaporation of which would initiate the arc. For arc currents up to 30 A, a zinc wire of 1 to 2 mm diameter was used, which yielded a considerable amount of vapour. With higher operating currents of 100 to 500 A it was found that the amount of vapour produced by the zinc wire was excessive, and that, in consequence, the vapour was blown from the orifice with great violence, which caused extinction of the arc. For high amperage, a brass wire of 0·3 mm diameter, which produced a smaller amount of vapour, was therefore used.

ARC CHARACTERISTICS.

In order to determine the voltage gradient along the arc, arcs of 68 mm, 54 mm, and 40 mm length were established through three orifices, two, and one orifice respectively, as indicated in Fig. 4. The results are charted in Fig. 5, which shows a gradient for amperages ranging from 10 to 400 A and indicates the existence of a minimum voltage gradient in the neighbourhood of 150 A. This feature appeared to be related to the orifice diameter. Where three orifices were used, the outer

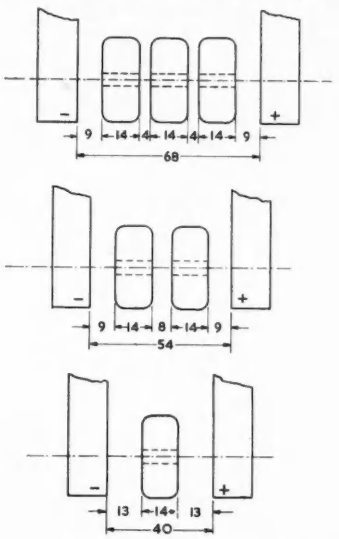

Fig. 4. **Arrangement of orifices for measuring voltage gradient.**

orifices were of 4·5 mm diameter bore and the centre orifice was of 21·5 mm diameter. At low amperage, the arc channel did not fill the bore of the orifice and the characteristic of the voltage gradient was dropping down to the amperage at which the arc channel filled the bore; from then onwards, the characteristic became a rising one. Lotz also measured the pressure prevailing in the bore of the orifice as a function of the amperage by tapping the bore without interfering with the flow of water in the bore, and obtained a rising characteristic, the pressure rising from 1 cm w.g. at 50 A to 16 cm w.g. at 400 A.

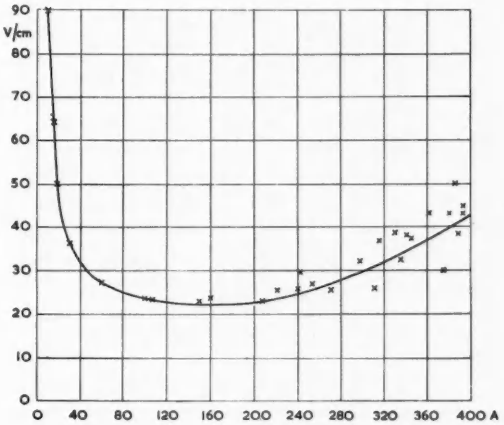

Fig. 5. **Voltage gradient characteristics of arc.**

It goes without saying that measurement of the high temperatures involved is a matter of great difficulty, and, in fact, proved impossible until a special analytical method based upon spectroscopic observations and theoretical considerations of the relationship between temperature and electron-ion density (Saha equation) was evolved. The application of this method to the temperature determination of the Gerdien arc is described by R. W. Larenz in detail in a recent paper[5]. No solid material is known at present which would remain in the solid phase at the temperatures involved, the highest melting point attained so far being that of tantalum-hafnium carbide, which is 4,200° K. The temperatures computed by Larenz, and claimed by him to have an accuracy of about ± 5 per cent, are summarised in the graphs reproduced in Figs. 6 and 7. Here, Fig. 6 gives the radial temperature distribution in the Gerdien arc as a function of the amperage for varying radial distances. The highest temperatures are, of course, encountered in the centre of the arc channel, and these are plotted in Fig. 7. It will be seen that with the lowest amperage used, which was 55 A, the maximum channel temperature still was some 13,000° K, while with 500 A it rose to some 34,000° K. (A temperature of 12,000° K in a spark was ascertained by J. D. Craggs and W. Hopwood in 1947[6]).

Referring again to the graphs Figs. 6 and 7, it will be noted that the increase of the temperature at the centre varies with the amperage. Thus, Fig. 6 shows a disproportionate jump in centre temperature between 100 and 150 A. Moreover, with 100 A, the radial temperature gradient is small in the neighbourhood of the centre, while with 150 A the gradient increases; with 200 A, the gradient near the centre is smaller than at 150 A; but it then increases rapidly at a radial distance of some 0·5 mm. As Larenz explains, these characteristics are due to changes in the thermal conductivity of hydrogen with the temperature. In theory,

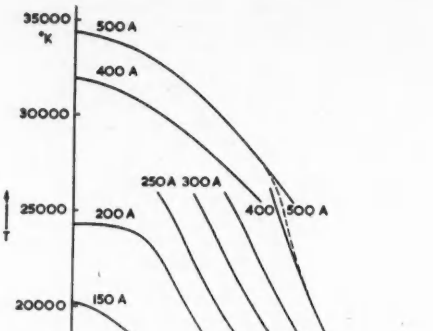

Fig. 6. **Radial temperature distribution in Gerdien arc.**

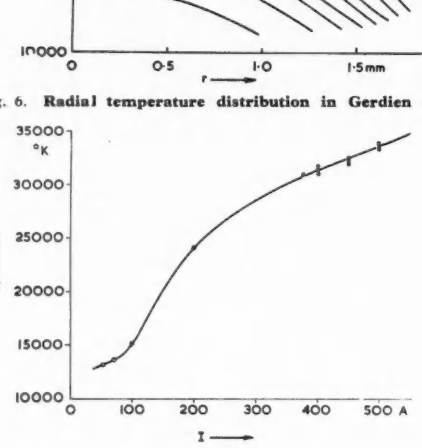

Fig. 7. **Temperature characteristic of core of Gerdien arc.**

the thermal conductivity of hydrogen has a first maximum at 15,500° K, then decreases and, between 20,000 and 25,000° K, passes through a minimum of about 1/6th the preceding maximum value, subsequently reaching a second maximum at about 30,000° K.

IMPROVED WATER ARC TECHNIQUE.

A considerable improvement in the operating characteristics of the water-cooled arc has recently been achieved by H. Maecker[7], who, with the design shown in Fig. 8, achieved arc temperatures far beyond those reached with the original Gerdien arc. As will be seen from Fig. 8, the arc burns in a duct of substantial length, formed by a water vortex rotating at high speed. As in the Gerdien orifice, the rotational movement of the water is due to the tangential entry of the water into the bore. The smallest water bore established in this manner was 1·4 mm in diameter, the body of water rotating at the rate of 700 rps in a casing of 35 mm internal diameter, the rotation being measured at the bore. The length of the water bore was 16 mm. The water escaping at the ends spreads out radially over the end shields, the surfaces of which are so shaped as to ensure adhesion of the water film. With a 1·4 mm dia. water bore, the diameter of the orifice in the end shields was 2 mm, which left only 0·3 mm water film thickness in the shields. By using transparent material for the housing, the burning of the arc in the water bore could be observed visually. For the purpose of making spectroscopic measurements of the arc channel, hollow carbons were used.

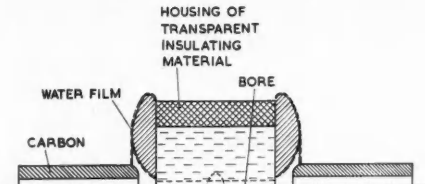

Fig. 8. **Water bore of Maecker arc.**

By maintaining an arc current of 250 A in the water duct, F. Burhorn and H. Maecker[8] could measure a potential gradient of 240 V/cm, and a current density of 17,000 A/cm² was achieved, which corresponded to a power consumption of 60 kW per cm length of arc channel. The temperature of the arc was found to be 35,000° K. When using a water bore of 2·3 mm diameter and passing an arc current of 1500 A, a maximum arc channel temperature of 50,000° K was recorded. In this case, the current density was 37,000 A/cm² and the specific power consumption was 450 kW per cm length of arc channel. On a volumetric basis, a power of 11,600 kW was expended per cm³ of arc channel. This is some 50 times the power released per cm³ in the Gerdien arc.

PLASMA PRODUCTION.

This enormous specific power input is used to evaporate water to dissociate the steam and to effect ionization, which results in the production of "plasma"—that is, a mixture of positive ions and negative electrons. Owing to the gas pressure produced in the arc channel, a long jet of plasma is ejected from both ends of the water bore and contacts with the electrodes, thus serving as electrical conductor between them. By passing the plasma jet through an orifice plate, the jet can be investigated over a part which does not carry any arc current. In this case, the plasma is in thermal equilibrium and consists almost wholly of electrons and protons, only one-sixth of the plasma being oxygen ions. Plasma is well known to astrophysicists as constituting the "atmosphere" of certain stars. Its properties are a mixture of the properties of gases, electrolytes, liquids, and metals. The scientific importance attaching to the production of plasma in such a simple manner can hardly be exaggerated. The possible utilization of plasma production for technical and chemical purposes is under consideration, but information on the nature of developments has not been published as yet.

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Heat-Resisting Sintered Aluminium

By R. IRMANN. (From *Revue de l'Aluminium*, Vol. 28, Nos. 179 and 180, July/August and September 1951, pp. 269-275 and 311-316, 24 illustrations.)

On sintering, the applied pressure plastically deforms the aluminium powder particles, thus breaking the hard oxide skin and welding the particles at intermittent junctions. As a result, the sintered article is coherent but the interspersed oxide inclusions reduce the ductility of the original metal and increase its resistance against plastic yield and rupture after yield. Unalloyed sintered aluminium thus possesses yield and rupture strengths equal to those of heat-treated aluminium alloys. The high melting-point oxides also prevent a pronounced drop in strength with temperature so that the sintered metal resists heat better than the usual aluminium alloys.

ALUMINIUM powder may be produced by atomisation of the liquid metal, by vibration of the near-liquid hot metal, or by dry or wet crushing. The first two methods result in equi-axial grains, usually of about 200 microns (8×10^{-3} in.) linear size, and the last two methods in flakes of 1 to 50 μ (0·04 to 2×10^{-3} in.) thickness or, under special conditions, of even less than 1 μ thickness. Since dry crushing needs special precautions against fire and explosion, the wet crushing method will be the most suitable. Ordinary commercial aluminium forms an oxide skin on exposure to air, the thickness of the skin increasing with time of exposure and reaching about 0·01 μ thickness after a few days. Assuming that the powdered aluminium flakes form oxide skins of this thickness, we may calculate the oxide content of the powder from the fineness of its particles (Fig. 1). The powder is first compressed cold under a pressure of 12

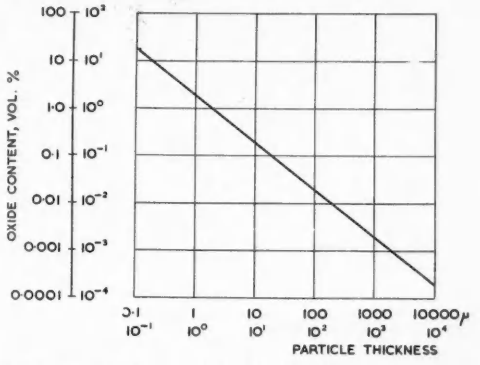


Fig. 1. **Oxide content of flaked aluminium powder as a function of the particle thickness.**

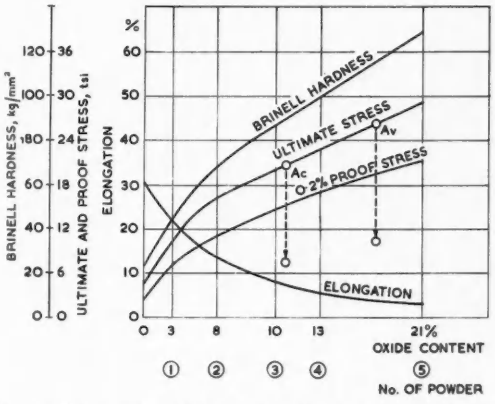


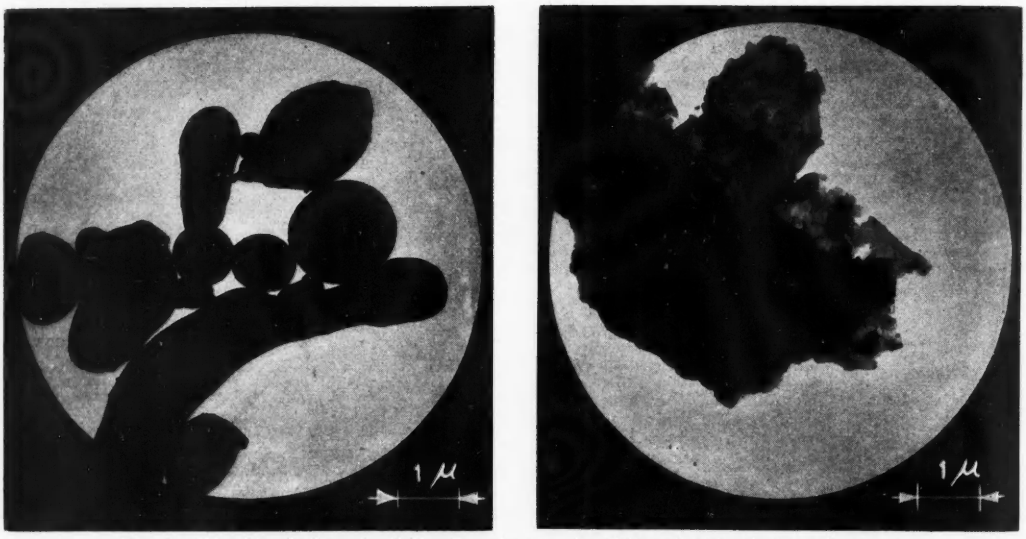
Fig. 2. **Influence of oxide content and fineness of aluminium powder on the mechanical properties of the sintered product at room temperature.**

Figs. 3 and 4. **Atomized powder** (above) **and crushed powder in flake form** (below).

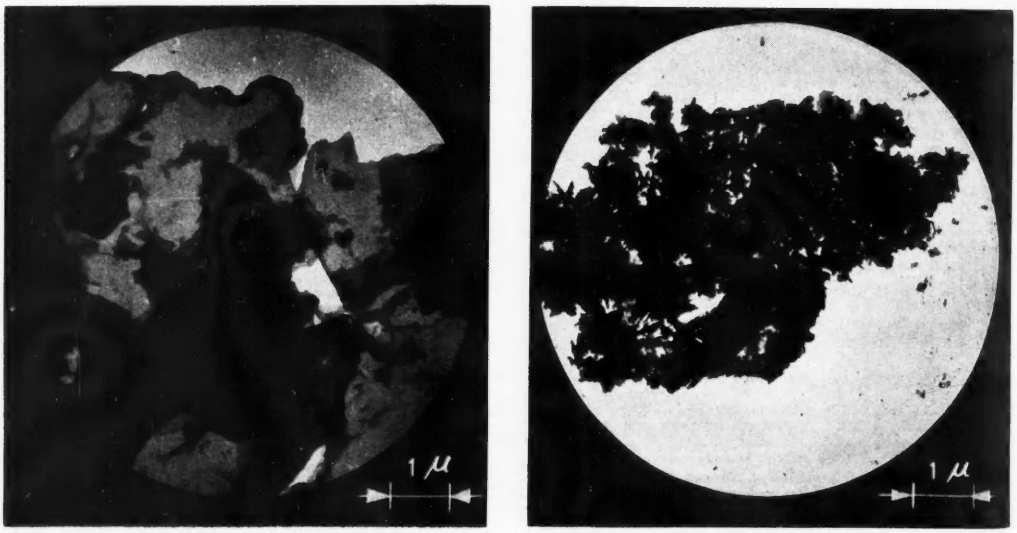
to 30 tsi, then sintered at 500 to 600° C under a pressure of 30 tsi, and finally extruded or die-pressed at the same temperature and under a pressure of 30 to 60 tsi. The strength of the sintered product at room temperature is many times that of cast aluminium and comparable to

that of heat treated Al-Cu (Anticorodal) or Al-Mg (Avional) alloys. Fig. 2 shows the mechanical properties of products sintered from powders of varying fineness (No. 5 being the finest powder) and values for Anticorodal (Ac) and Avional (Av) are given as a comparison ; the figures for zero per cent oxide are those of the cast metal. These qualities are due to the oxide skin enveloping each individual powder particle. On sintering, the skin is broken and the particles weld together, perhaps only at single points, but nevertheless so as to give sufficient cohesion to the product. Since the oxide skin still isolates each particle over most of its circumference, recrystallisation or grain growth are inhibited even at elevated temperatures. Thus, whilst heat-treated alloys lose their strength by heating at 400° C, the properties of the sintered product remain unaffected even by prolonged heating at 500° C.

Figs. 3 and 4 show the equi-axial grain of atomized powder and the flake form of crushed powder. Under an electron microscope with $\times 10{,}000$ magnification, the atomized powder appears opaque, whilst the flakes are translucent, thus indicating a thickness of little more than $0{\cdot}01\mu$ in many cases (Figs. 5 and 6). If the powder is heated in a stream of hydrochloric acid, the aluminium sublimes, leaving the oxide skin as a shell, and again, under the electron microscope, it can be seen that the skin of atomised particles is $0{\cdot}03$ to $0{\cdot}3\mu$ thick, crystalline and brittle. Under pressure, it will break into finely divided impurities inside the material (Fig. 7). On the other hand, the skin of the flakes is less than $0{\cdot}01\ \mu$ thick, amorphous, and of a certain ductility (Fig. 8), so that even if broken it maintains a partial cohesion. The skin thickens with increasing *length of exposure* to the atmosphere, especially at elevated temperatures so



Figs. 5 and 6. **Atomized powder** (left) **and crushed powder** (right) **under the electron microscope.**



Figs. 7 and 8. **Oxide skins of atomized powder** (left) **and crushed powder** (right) **under the electron microscope.**

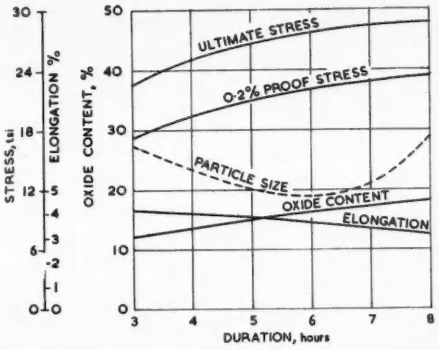


Fig. 9. **Influence of the duration of the crushing process on the particle size and oxide content of the powder and on the mechanical properties of the sintered product.**

that the oxide content of the powder and, therefore, the strength of the sintered product then also increases. However, as the skin approaches a certain limiting thickness, so do the mechanical properties, and further exposure then no longer improves the sintered product. *Prolonged crushing treatment* of the flake powder should improve its fineness, but beyond a certain duration the particles begin to agglommerate to flakes of larger surface area though the thinness is maintained. With increasing surface area, the oxide percentage and the sintered strength must also increase (Fig. 9) so that not only the powder fineness but also the particle shape influences the sintered properties. We must conclude that, after a normal crushing treatment, the oxide skin does not yet prevent partial recrystallisation during sintering, and that the effect of recrystallisation is smaller, the thicker and more extensive the skin.

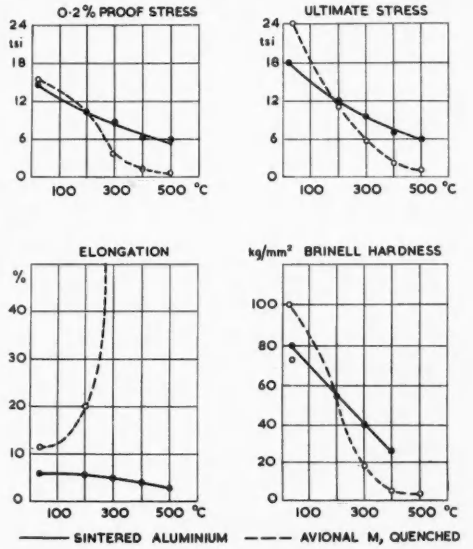


Fig. 10. **Mechanical properties at elevated temperatures after 30 days' heating at test temperature.**

If an aluminium powder of a fineness between No. 3 and No. 4 is sintered, and the sintered product tested at an elevated temperature after being held for one month at that temperature, then its strength is seen to

TABLE I. MECHANICAL PROPERTIES AT ROOM TEMPERATURE AFTER PROLONGED HEATING.

Material	Treatment	Ultimate stress tsi	0·2% Proof stress tsi	Elongation %	Brinell Hardness kg/mm²
Sintered aluminium	extruded	21–23	15–17·5	6–8	100–110
	after 1 mth. at 500° C	20–22·5	14–17	6–8	95–105
Anticorodal (A-SG) (Al-Cu alloy)	quenched, tempered after 1 day at 400° C	21–27	17·5–25	10–14	90–120
		6·5–9	2·5–5	20–30	30–40
Avional (A-U4G) (Al-Mg alloy)	quenched after 1 day at 400° C	26–31	17–23	12–20	100–125
		12–16	5–8	10–20	50–65

decrease, though not at the same rate as that of a heat-treated Al-alloy (Fig. 10). The elongation of the sintered product also decreases whilst that of the re-crystallising alloy increases very steeply. The superior *heat resistance* of the sintered unalloyed aluminium is still more strikingly displayed by the fact that, if tested at room temperature after one month's heat treatment at 500° C, the sintered product loses practically nothing of its strength (Table I). Even after very prolonged heat-treatment at 250° C, its proof stress remains unimpaired (Fig. 11). The *creep qualities* of sintered aluminium are also superior to those of A1-Mg (Avional) alloy. According to Fig. 12, a stress of 5·7 tsi is still safe at a temperature of 250° C while Avional will break in 1000 hours under a stress of 3·8 tsi at the same temperature. Fig. 13 gives safe creep limits for

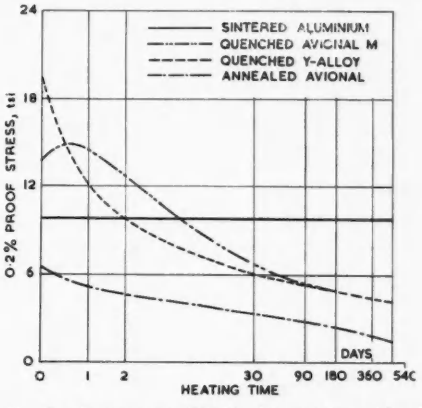


Fig. 11. **Proof stress at 250° C after prolonged heating at 250° C.**

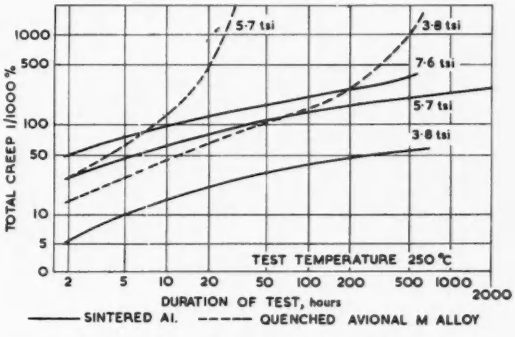


Fig. 12. **Creep curves of $^3/_8$ in. dia. specimens.**

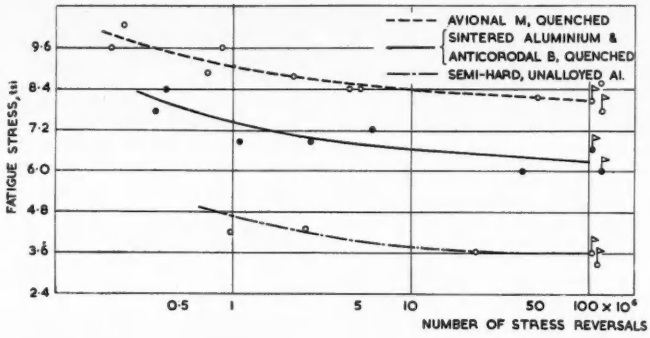


Fig. 14. **Fatigue curves for stress reversal at room temperature, polished specimens of 3/8 in. diameter.**

various temperatures, as found by the Rohn test method. In these tests, the load is kept constant and the temperature controlled by the total creep elongation of the specimen until equilibrium is reached. With sintered aluminium, equilibrium is established after a few days; heat-treated alloys reach equilibrium only after partial or full recrystallisation, depending on the final test temperature. *Fatigue curves* are shown in Fig. 14 and the influence of notches on the fatigue limit is given in Table II. Repeated loading from zero to maximum at various temperatures leads to fatigue limits as shown in Fig. 15 if tests are taken up to about 2 million cycles. Tests of longer duration indicate that these limits remain stable for sintered aluminium but drop appreciably with the progressive recrystallisation of heat-treated alloys.

TABLE II. INFLUENCE OF NOTCHES ON THE FATIGUE LIMIT AT 100 MILLION STRESS REVERSALS.

Material	Fatigue limit in tsi²		Notch fatigue ratio
	unnotched	notched	
Avional M, quenched	8·8	6·1	1·44
Anticorodal B, quenched	6·8	5·85	1·17
Sintered aluminium	6·8	4·85	1·40
Unalloyed semi-hard Al	3·9	2·9	1·33

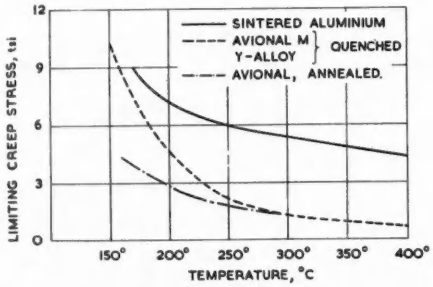


Fig. 13. **Creep limits after 30 days at controlled temperatures and constant loading (" Rohn " tests).**

The *electrical and thermal conductivity* of the sintered product depend on oxide content and method of manufacture. The oxide inclusions interrupt the continuity of the metallic structure and thus diminish the conductivity; the production method may influence the particle orientation and, therefore, the conductivity to a small extent. In general, as the oxide content increases from 10 to 21 per cent, the electrical conductivity drops from 25·9 to 18·4 metres per ohm per mm². Nevertheless, the conductivity of sintered aluminium is still superior to that of heat-treated Al alloys (Table III). The *thermal expansion* of sintered aluminium between 20 and 100° C is less than that of the alloys (Table III).

TABLE III. ELECTRICAL AND THERMAL CONDUCTIVITY, AND THERMAL EXPANSION, IN PER CENT OF THE CORRESPONDING VALUES FOR ALUMINIUM OF 99·5 PER CENT PURITY.

Material	Electrical conductivity	Thermal conductivity	Thermal expansion
Sintered aluminium	70	77	80
Avional M, quenched	60	65	93
Y-alloy, quenched	50	60	88

No transformation of the crystalline structure takes place, hence no permanent volume change can appear. The *corrosion resistance* against atmospheric action, boiling water, and weak acids is the same as that of commercial aluminium, the resistance against sea water approaching that of Al-Cu (Anticorodal) alloys.

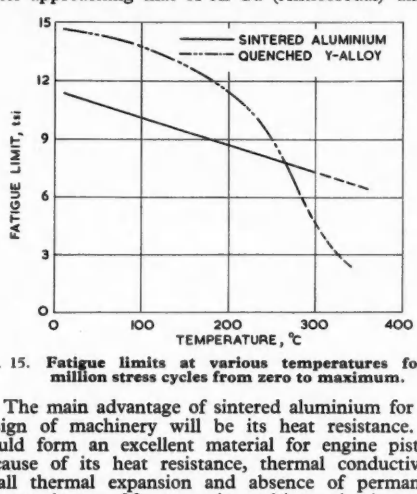


Fig. 15. **Fatigue limits at various temperatures for 2 million stress cycles from zero to maximum.**

The main advantage of sintered aluminium for the design of machinery will be its heat resistance. It would form an excellent material for engine pistons because of its heat resistance, thermal conductivity, small thermal expansion and absence of permanent volume change. Moreover, its melting point is appreciably higher than that of Al-alloys, so that overheating (e.g., in Diesel engine pistons) is less likely. The high temperature fluctuations in I.C. engines severely stress the piston material, and we may deduce from the creep and fatigue curves of the sintered aluminium that the admissible working stresses under such conditions will be many times higher for sintered aluminium than for Al-alloys used at present. The higher strength of the sintered material would permit fabrication of the pistons with high-strength sintered inserts produced to the desired shape by die pressing. The blades of air compressors for gas turbines could well be made from this material and, quite generally, the existence of a heat-resistant light metal will offer new possibilities for the design of various types of machinery.

Increase in Adhesion of Shrink Fits by Surface Oxidation

By F. WENCK. (From *Werkstattstechnik und Maschinenbau*, Vol. 41, No. 9, September 1951, pp. 359-361, 5 illustrations.)

The following article deals with the influence of surface layers on shrink fits subjected to torsional load. Evidence is submitted on the decrease of adhesion due to oil films on the steel surfaces and on the increase due to oxide layers.

PRESS fits and shrink fits are being increasingly used as an aid in machine construction. The adhesion strength or maximum possible loading of a press fit is greatly influenced by the adhesion factor of the contacting surfaces. This adhesion factor and its influence on adhesive strength of shrink fits[1,2] and means of increasing it[3,4] have formed the subject of many investigations. It was found that adhesion is increased by oxidation of the joint surfaces as compared to surfaces in a normal condition ; this, however, does not apply to longitudinal press fits. The investigations described below are limited to lateral press fits, and shrink fits in particular, of components in 45-tsi steel ; the elastic deformation of these was taken into consideration. The contacting surfaces were ground and lapped and their average surface finish was 2 to 5μ ($1\mu = 10^{-3}$ mm).

CALCULATIONS FOR SHRINK FITS.

Calculations relevant to press fits and shrink fits (Fig. 1) have previously been dealt with in some detail by Kienzle and Heiss[5]. The notation in the equations given below is as follows :—

Z = Adhesion interference ; $Z = U - 2\,(G_A + G_I) = U - 2g$;
U = nominal interference ;
G_O, G_I = surface finish value of outer and inner components ;
L = length of fit ;
R_{Oo} = outside radius of outer shrink fit component ;
R_J = radius in the joint ;
p = pressure in the joint ;
σ_{FO} = yield point of material forming outer component ;
E = modulus of elasticity of steel ;
M_{tt} = torque required for loosening the joint of the shrink fit tangentially ; and
γ_{tt} = adhesion factor corresponding to M_{tt}.

The following equations are valid only when the inner component of the fit is solid and when both components are made of steel. According to the well-known principles used in thick-walled tube calculations, the pressure in the joint of a shrink fit is as follows :—

$$p = \frac{Z\,E}{2\,R_J}\left(\frac{R_{Oo}^2 - R_J^2}{2\,R_{Oo}^2}\right) \quad .. \quad (1)$$

Considering the relationship of surfaces and forces in a shrink fit subjected to torque as in Fig. 1, the following expression for the torque required for a relative rotational movement between the outer and inner components is obtained :

$$M_{tt} = E\,\pi\,R_J\,L\left(\frac{R_{Oo}^2 - R_J^2}{2\,R_{Oo}^2}\right) Z\,\gamma_{tt} \quad .. \quad (2)$$

Where the values of R_J, L, R_{Oo}, U and G_O, G_I and, consequently, of the adhesion interference are known, the adhesion factor can be determined after measuring the torque M_{tt}.

$$\gamma_{tt} = \frac{M_{tt}}{E\,\pi\,R_J\,L\,Z}\left(\frac{2\,R_{Oo}^2}{R_{Oo}^2 - R_J^2}\right) \quad .. \quad (3)$$

The initial eq. (1) is only valid for the range of elastic deformation. If, however, the two components of the shrink fit become plastically deformed, the calculation of pressures and maximum torsional loadings cannot be carried out so easily and without further data. Information on this is given by Kienzle and Heiss[5].

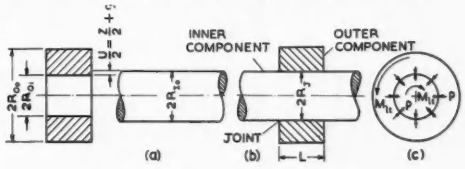


Fig. 1. **Shrink fit.**
(a) Inner and outer component of the joint ; interference U.
(b) Inner and outer component as fitted.
(c) Shrink fit under torsional loading ; pressures in the joint.

The pressure in the joint p, due to the interference Z (see eq. (1)) produces tangential and radial loading of the inner and outer components of the shrink fit. The maximum loading occurs tangentially on the radius R_{Oi} of the outer component. Assuming constant strain, the principle of purely elastic deformation applies in this critical zone :—

$$Z_{\text{permissible}} \leq \frac{4}{\sqrt{3}} R_J \frac{\sigma_{FO}}{E} \quad .. \quad .. \quad (4)$$

The maximum permissible transmissible torque $M_{tt\,max}$ can easily be determined, assuming the relationship in eq. (4) to be true for the purely elastic deformation in the measurement of the shrink fit, and using eq. (2). It is :—

$$M_{tt\,max} = \gamma_{tt}\left[\sigma_{FO}\,\pi\,\frac{2}{\sqrt{3}}\,L\,R_J^2\left(\frac{R_{Oo}^2 - R_J^2}{R_{Oo}^2}\right)\right] \quad (5)$$

Providing that dimensions R_{Oo}, R_J and L of the shrink fit and the material of the components are given, and if the adhesion interference Z is limited according to eq. (4), the only method of increasing the torque required for loosening the joint M_{tt} is by raising the adhesion factor γ_{tt}.

ADHESION FACTOR AND THE SURFACE.

Many investigations into the field of dry friction have shown that the coefficient of friction is considerably influenced by the condition of the contacting surfaces. Information on this, relevant to press fits, is given in a report by Kienzle[6].

Studies of the surface condition of solids have further shown that the surfaces are invariably contaminated by surface films or layers. These films are firmly attached to the base material and in some cases there is a chemical bond. They can therefore only be removed with difficulty. The surface of steel is also not completely pure, and even during metal cutting operations, gaseous, liquid or oxide films are immediately formed due to chemical contamination. The thickness of these layers cannot be measured with normal measuring apparatus, but it is known to be considerably less than 1 μ.

Despite their minute thickness, these films exert a great influence on the adhesion factor ; in fact, the measured adhesion factor values refer to the surface films rather than to the base material. The adhesion

factor is reduced by these films as compared to pure metallic contact. Adhesion is particularly reduced by oil films and these films are almost invariably present on steel surfaces in industrial surroundings. Contrary to these findings, however, oxide films normally present in shrinking operations using heat, and evidenced by tempering colours, increase adhesion.

SURFACE TREATMENT TO INCREASE THE ADHESION FACTOR*.

(a) *Investigations into the removal of oil films from steel surfaces.* The obvious measures are the removal of the harmful oil films by washing off or by absorption by a third material. In such cases, the affinity of oil for such materials must be greater than for steel.

Ether and benzene are well known solvents for oils and greases and the great affinity of oil for chalk is also generally known. Treatment with these materials should be carried out only shortly before the shrinking operation. Fig. 2 shows the adhesion factors γ_{it} resulting from such treatments.

Results of ether and benzene cleaning treatments (curves *b* and *c*) are not satisfactory as they do not appreciably increase the normal adhesion factor γ_{it} of 0·3. Traces of oil apparently remain on the surfaces. Considerable increases in the adhesion factor values γ_{it} (curve *a* in Fig. 2) are due to the chalk absorption treatment, as it appears to be almost completely successful in removing the oil.

(*b*) *Investigations into the production of films increasing adhesion.* When the outer component of the shrink fit is heated in the presence of atmospheric oxygen, oxide surface films are produced. In general, these oxide films prevent contamination by oil prior to the production of the shrink fit joint. Existing oil films are possibly also removed by burning off at the temperatures required for the shrinking operation.

The adhesion factor can be increased up to 0·4 by these means without special cleaning. The increased adhesion resulting from the chalk treatment could also be partially ascribed to oxide films. Normally however, it is only the outer component of the fit which is subjected to heating. To achieve a further increase in the value of the adhesion factor γ_{it}, it would be desirable to subject the inner component of the shrink fit to heating, to produce an oxide film. It would, of course, have to be cooled again prior to the fitting and would have to be kept scrupulously clean in the meantime.

The adhesion factor values resulting from this treatment (curve *d* in Fig. 2) are considerably higher than normal ones and can only be achieved in press fits with granular particles in the joint. This is no doubt due to the fact that the oxide films are almost free of friction-reducing layers such as oil films.

The oxide film does not affect the interference U, as only prolonged heating of steel in air would produce measurable scaling. It is not certain whether scale would increase adhesion in the same manner as oxide films (tempering colours).

*These investigations were carried out at the Institute for Machine Design, with the assistance of the Institute for Machine Tools at Hannover University.

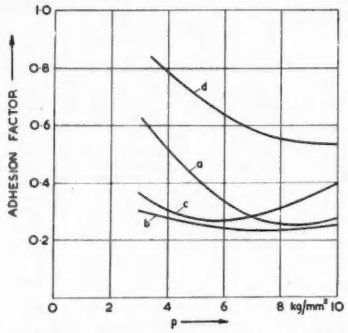


Fig. 2. **The effect of pressure p on the adhesion factor γ_{it} with various surface cleaning treatments. Both components are made of 45-tsi steel with ground surfaces.**

Curve (a) Both components degreased with chalk. The outer component oxidised by heating to 300° C.

Curve (b) Both components degreased with commercial benzene. Oxidising treatment as with (a).

Curve (c) Both components degreased with double-distilled ether. Oxidising treatment as with (a).

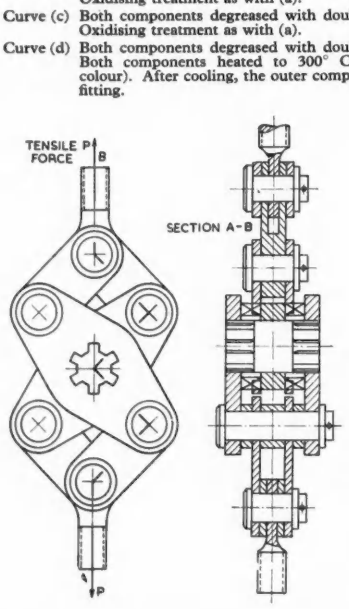
Curve (d) Both components degreased with double-distilled ether. Both components heated to 300° C (blue tempering colour). After cooling, the outer component reheated for fitting.

EXPERIMENTAL PROCEDURE.

The test results quoted above were obtained in two independent test series, with different given data. They correlate completely and are repeatable. The shrink fit components were made of 45-tsi steel, and the joint was subjected to a static load test.

The data are :

		1st test series	2nd test series
$2\,R_j$	[mm]	15	60
$2\,R_{o_o}$	[mm]	25	100
L	[mm]	10	40
Surface finish outside	[μ]	1–2	2–5
Surface finish inside	[μ]	1–2	2–5
Type of surface	..	ground/lapped	ground



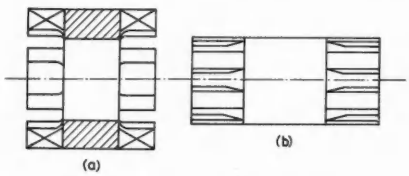


Fig. 3 (left). **Torque mechanism.**

Fig. 4 (above). **(a) Outer component. (b) Inner component.**

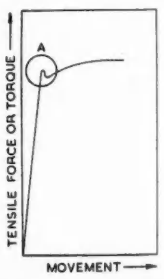


Fig. 5 (right). **Graph of force plotted against movement; Point A indicates loosening torque M_{lt}.**

The torsional loading mechanism used in the 2nd test series is shown in Fig. 3 and is mounted in a tensile testing machine. The inner and outer components of the fit have wedge-shaped slots and are held from both sides by side plates with corresponding profiles. The exerted torque can be determined, bearing in mind the transmission ratios and losses in the mechanism.

The graph of force plotted against movement (Fig. 5) clearly indicates the point *A*, where sliding of the joint commenced, i.e., the beginning of the relative movement between the inner and outer components. This provides

(*Concluded on page* 28)

SWITZERLAND

Problems of Fluid Measurement

By M. SCHATZMANN. (From *Schweizerische Technische Zeitschrift*, No. 43, October 25, 1951, pp. 747-751, 15 illustrations.)

Problems of measurement connected with the intake or delivery of fluids are common in industry. The object of measurement usually relates to consumption or the maintenance of a given mixture ratio. The article illustrates, by means of practical examples, the solution of such problems.

1. FLOWMETERS.

(a) *Multi-jet Propeller Instruments.* Domestic water consumption meters fall into this category. Normal range from 100 to 1100 cu ft, for supply pipes having diameters from ½ in. to 2 in. The lower limit at which meters are still accurate to ±2 per cent, depending on the size and construction, ranges from 2·5 to 40 gph. They are thus unsuitable for the measurement of very small rates of flow.

(b) *Woltman Meters.* These are typical flowmeters, worked by a form of Kaplan turbine. Their capacity is much higher and, thus, their lower limit of accuracy is also higher than that of the multi-jet instruments, ranging from 2·5 to 250 gpm.

(c) *Quantity Meters.* In this category belong e.g. rotary piston meters, gas meters and the GWF quantity meter. The latter uses two fixed volume measuring chambers, which are successively exhausted by means of flexible membranes. The accuracy of this instrument is such that it can measure a flow of 1¾ pints per hour accurately.

(d) *Woltman Compound Meters.* For large variations of flow rates, the Woltman meter can be combined with a multi-jet meter, so that smaller rates of flow are measured on the multi-jet instrument and higher rates on the turbine meter. The instruments are automatically brought into action by means of a hydraulic selector valve (Fig. 1).

2. ELECTRICAL INDICATION OF CONSUMPTION.

Meters are sometimes in inaccessible positions, in which case they are combined with electric relays giving off impulses after the consumption of a given unit of quantity. These impulses are then registered step by step on a conveniently located counter.

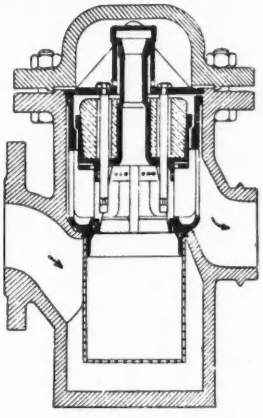


Fig. 1.

3. ELECTRICAL REGISTRATION OF RATES OF FLOW.

The counter here is replaced by a graphical indicator showing the rate of flow directly. An integrating meter also gives the total consumption. The rate of flow is established through the number of impulses received from the relay during a fixed measuring interval.

4. DOSAGE CONTROL UNITS WITH ELECTRICAL PRE-SELECTOR GEAR.

Fig. 2 shows the principle of such a dosage control unit. The required amount is set on the pre-selector WR and then the contact JS is closed, causing the magnetic valve MV to open. The flow is now registered on the step-by-step indicator SR. When the indicated

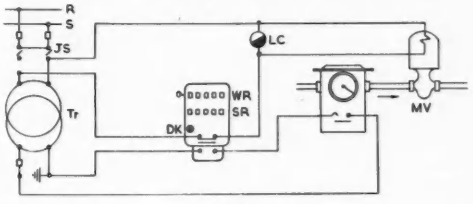


Fig. 2.

amount reaches the pre-set value, the switch KSR closes the valve MV and simultaneously extinguishes the pilot light LC. To allow another similar dose through, the pre-selector can be reset by pressing button DK. If a different dose is required, the switch JS must be broken and the selector WR set to the new value. Several pre-selectors may easily be combined to provide a programme of different dosages.

5. PNEUMATICALLY OR HYDRAULICALLY CONTROLLED DOSAGE UNITS.

Fig. 3 illustrates a dosage control unit containing a

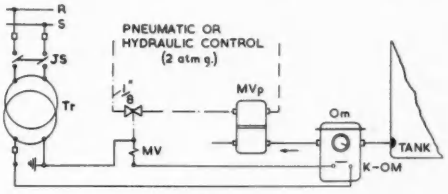


Fig. 3.

pneumatically or hydraulically operated membrane valve MVp. The counter Om is provided with a zero point contact K-Om. On making the contact JS, the magnetic valve MV operates the hydraulic valve MVp which, in turn, opens the supply route. The counter, moving backwards from the present value, actuates the switch K-Om when it reaches zero, and the switch closes the valve MV, thus cutting off the supply through MVp.

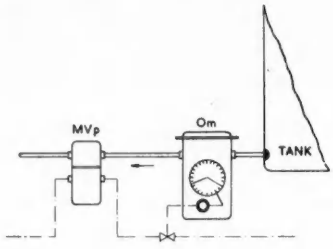


Fig. 4

Purely pneumatic or hydraulic control systems may be required in applications where the danger of explosion makes electrical installations undesirable. Such a system is shown schematically in Fig. 4.

6. Electrical Dosage Control Units for Laboratories, etc.

To enable a continuous check to be made on the dosage process, a circuit according to Fig. 5 is employed. The indicator LW is set against the required amount on the large dial of the dosimeter DU. The moving

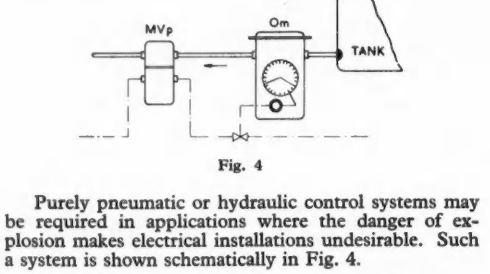


Fig. 5

pointer LL is driven round step by step by impulses coming from the volume meter Om through the contact K-Om. When the two pointers coincide, switch KDU is broken, closing the valve MV.

7. Dosage Units for Automatic Admixture of Chemicals, Depending on Water Consumption.

Fig. 6 shows the principle of a system, whereby, e.g., two different liquids may be added to a third, in quantities which depend on the consumption of the third liquid. Normally, the admixture ratios are fixed,

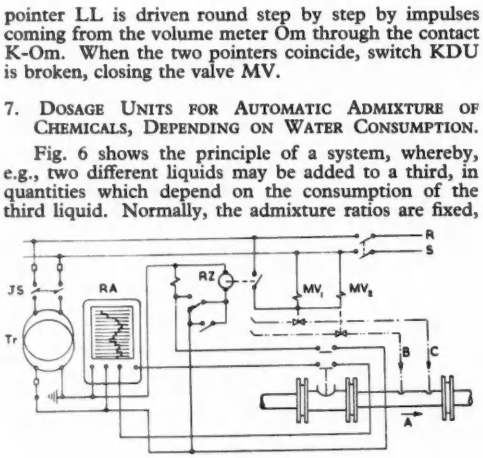


Fig. 6

and the added liquids B and C are either directly run into the main pipe, or are injected by means of membrane pumps. In the former method (illustrated), the supply of B and C is controlled by valves MV_1 and MV_2, which are operated through a time relay RZ coupled with a synchronous motor. In this way the valves are opened for a given period of time, to allow a predetermined amount of each liquid to pass. The graphical indicator RA registers the consumption of liquid A.

8. The GWF Hot Water Slot Meter.

This system works on the coin-in-slot principle (Fig. 7). When a coin is inserted into St, the contact K-St sends a current pulse to the trigger-relay R. This closes switch KR and brings valve MV and pilot lamp

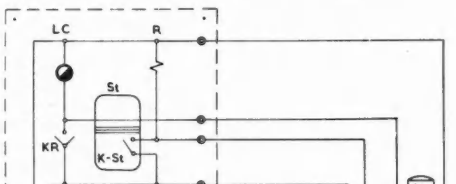


Fig. 7

LC into operation. Whenever hot water is consumed, the meter operates and, when the amount paid for is used up, closes the switch K-Wm. This switch brings the trigger-relay R into action, which closes valve MV and extinguishes the pilot lamp.

9. The GWF Indirect Measuring System.

The measurement of highly impure liquids containing some solid matter has hitherto caused great difficulties, as all types of meters were soon put out of action. The indirect GWF method can in such cases be employed, provided the temperature of the liquid is approximately constant. The principle of the method is that instead of the liquid, the air displaced by it or streaming after it (vapours or gases) is measured, as is indicated in Fig. 8. The highly sensitive air meter

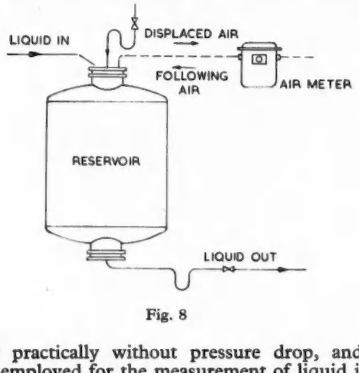


Fig. 8

operates practically without pressure drop, and can thus be employed for the measurement of liquid intake and outflow, and can also be arranged so that it indicates the contents of the reservoir. To allow for temperature variations as well, the newer instruments are equipped with adjustable counters and indicators, so that the meter can be set to the prevailing temperature conditions.

Regenerative Braking of Hydraulically-Driven Centrifuges

By P. C. W. PULLES. (From *De Ingenieur*, Vol. 65, No. 43, October 26, 1951, pp. Ch 59-62, 1 illustration.)

It can be said that a centrifuge with a hydraulic drive and braking arrangement has the following advantages over an electrically-driven centrifuge which is braked by mechanical or electrical means: (a) less power consumed, (b) no brake wear, and (c) less maintenance. The hydraulic equipment for energy recuperation described in this article comprises a hydraulic drive which operates as a pump during the braking process.

THE PRINCIPLE OF REGENERATIVE BRAKING

The possibilities of energy recuperation during braking are considerable, since the centrifuge baskets are generally started and stopped at frequent intervals (for instance, 6 to 20 times per hour). To obtain an idea of the large quantities of energy involved, we shall consider a typical example.

A filled centrifuge basket has a mass of 400 kg and a WR^2 of 200 kgm^2. In order to accelerate it from zero to 1400 rpm during one minute, a power of 72 kilowatts (or 98 hp) is required. At maximum speed, the kinetic energy of the centrifuge basket is then considerable and amounts to approximately 211,000 kgm or 540 kilogram-calories.

When a centrifuge is coupled to an ordinary flexible band brake, the energy of the rotating basket is wasted during braking by dissipation of heat. Cooling air is required to maintain the brake temperature at a low value. Moreover, as a short braking period is desirable to maintain a high rate of production, the result is a high rate of wear of the brake linings.

Various methods have been developed for the recovery of the kinetic energy available during braking. A band brake can still be used as an auxiliary brake, but in this case it will be subjected to considerably reduced loads and, therefore, have a longer life. Electrically-driven centrifuges with a regenerative system feed back the braking energy into the network. These systems will be described in the next section. Further advantages can be obtained with hydraulic equipment, as shown later on in this article.

ELECTRICAL REGENERATION

For centrifuges driven by d.c. machines, energy recuperation is difficult, since it would require the installation of a converter or a rectifier. The initial and maintenance costs of such units are extremely high and are justifiable only for much higher powers than those occurring in centrifuge installations.

Energy recovery is more easily obtained with three-phase machines. During the braking process, the motor is allowed to operate as a generator running above synchronism in the same direction of rotation as the electrical three-phase field of the stator. The synchronous speed being determined by $n = 60f/p$ (where f = network frequency, and p = number of pole pairs), the rotational speed of the three phase field can be decreased by altering the value of either f or p.

The first method can be adopted where two network frequencies are available. The squirrel cage motor and the slip ring induction motor are suitable for this work. Assuming the second network frequency is only one half of the first, a regenerative braking action will be obtained when the lower frequency network is connected to the motor. Disregarding heat losses, approximately three quarters of the kinetic energy of the basket will be usefully converted again into electrical power before the motor speed has fallen to the synchronous speed value. The motor is then brought to a standstill by means of a counter current or by mechanical action. A second regenerating stage with a still lower frequency for the network voltage is possible in theory, but rarely practicable since it involves expensive additional equipment.

The second method is also applicable to the squirrel cage motor or the slip ring induction motor. The number of pole pairs p is varied in order to obtain various synchronous running speeds. In the case of the squirrel cage motor, the alteration affects only the number of pole pairs of the stator, whereas with the slip ring induction motor it is also necessary to switch in further pole pairs in the armature circuit. This makes the latter arrangement rather complicated, so that in practice the squirrel cage motor is preferred for speed regulation.

The braking effect is obtained by switching in, for instance, twice as many pole pairs as are normally used. The motor speed will then be twice as high as the synchronous speed. While the speed of the centrifuge decreases to this lower value, the motor acts as a generator and its energy is fed back into the network. A second pole changing operation is rarely used owing to cost considerations and the motor is stopped in the manner previously mentioned.

A further possibility is the use of a Schrage type three-phase commutator motor. This machine operates as an asynchronous motor in its lower speed range when it is supplied with a counter current for starting or braking. In its regulating range, which is generally between 500 and 1500 rpm, the motor can be compared with a d.c. motor in a Ward-Leonard arrangement. It gives ideal energy recuperation throughout the regulating range during the braking process, and in regard to energy consumption its use with centrifuges is a considerable advantage. However, the Schrage motor is expensive and intricate in design, particularly when compared with the other two types of motor already considered.

HYDRAULIC RECUPERATION

The principle of the hydraulic method is substantially similar to the one applied in the electrical method of recuperation. The energy is recovered by means of a hydraulic motor. This drives the centrifuge during starting and normal running conditions, and operates as a pump during the braking process.

The hydraulic driving motor receives the energy required for the starting and running of the centrifuge from a continuously operating pump which supplies it with oil under pressure. The potential energy of pressure is thus converted into kinetic energy of rotation. For braking, the hydraulic motor is connected so that it will function as a pump. It is then driven by the rotating centrifuge basket and returns oil under pressure into the oil lines, thus converting kinetic energy back again into potential energy.

It is evident from the above that the possibilities of hydraulic energy recuperation depend on the efficiency of the hydraulic equipment available. In fact, there are various hydraulic motors on the market which meet the requirements. The components and connections are of simple design and the motor efficiency in starting and braking is approximately 90 per cent.

DETAILS OF THE HYDRAULIC SYSTEM

The system comprises a pump (1), a pressure chamber (7), a sleeve-valve control (8), a filter (3), and a relief valve (13), which form a closed circuit. Compared

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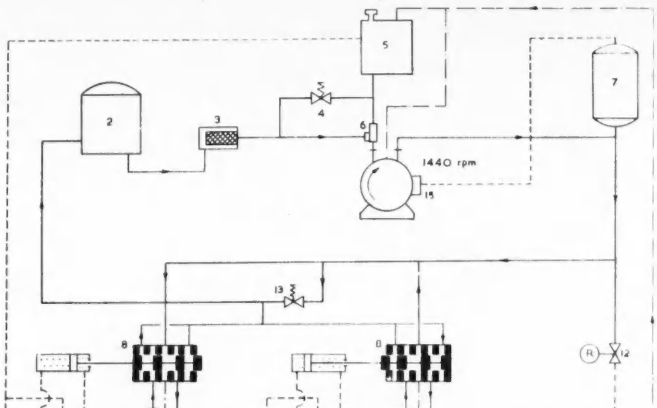
Fig. 1. **Schematic circuit diagram of hydraulic system with regenerative braking.**

1 pump
2 tank
3 filter
4 unloading valve
5 atmosphere tank
6 injector
7 pressure chamber
8 control sleeve
9 non-return valve
10 centrifuge
11 centrifuge
12 reducing valve
13 relief valve
14 four-way cock
15 positional regulator.



with an open arrangement, this closed circuit has the advantages of a reduced risk of air locks occurring and of a slower rate of oxidation of the oil.

The tank (2) is a reservoir on the suction side of the main supply pump (1). It is also used as an oil cooler. A drawback of the closed circuit arrangement is that the same oil is always circulating in the system and the oil temperature is therefore higher than in an open circuit under otherwise similar conditions.

The oil is drawn out of the tank (2) by the pump (1) through the filter (3). To avoid cavitation effects during starting and to compensate for leakage losses, the system is provided with an injector (6), through which oil can also be taken from the atmospheric tank (5) under certain conditions. Conversely, if there is an excess of oil in the circuit, this can be released through the unloading valve (4). The tank (2) and the pressure chamber (7) are of the "bladder" type, with a rubber membrane separating the oil from the air or nitrogen situated above it in the container.

If the oil delivered by pump (1) exceeds the capacity of the hydraulic motors, the pressure of the system will rise and cause the operation of the relief valve (13). This is an uneconomical condition, since the oil will then flow from the pressure pipe to the return circuit without producing useful work. To avoid this, a positional regulator (15) is provided on the pump (1), which controls the displaced volume of the pump when a certain pressure is reached. Pump (1) operates continuously, but its delivery depends on the pressure in the chamber.

The sleeve valves (8) can be set for starting and continuous running of the centrifuge, as shown for the centrifuge (10), or for braking, as shown for the centrifuge (11) in Fig. 1. Under starting and continuous running conditions, the oil flows out of the pressure pipe, through the sleeve valve unit and the centrifuge motor, and into the return pipe.

The motor is specially constructed so that any required torque between zero and the maximum value may be adjusted by means of a handwheel. This gives an infinitely variable speed adjustment which is very important for the filling of the basket at a specified speed, for instance 400 rpm, and continuous operation for dry centrifuging at maximum speed.

When the sleeve control is in the braking position, the rotation of the centrifuge basket drives the hydraulic motor (11), which then operates as a pump, drawing oil out of the return pipe and forcing it back into the pressure pipe. During braking, the pressure of the oil is thus raised to a higher level. A non-return valve (9) is provided in the system to prevent the sleeve from remaining too long in the braking position, since this would tend to reverse the direction of rotation and make the pump operate again as a driving motor.

The sleeve controls (8) are operated hydraulically by means of a servomotor. The adjustment of the end-positions for starting and braking is obtained by means of a four-way cock (14). When this is in its centre position, the sleeve is in its "off" position and the corresponding motor drive is then inoperative. The servomotor control lines operate at reduced pressure, this being achieved by means of the reducing valve (12). Leaking oil is returned through leakage pipes to the atmospheric tank.

CONCLUSION

The hydraulic system described above, apart from mechanical losses, provides complete energy recuperation during braking.

Regenerative braking is obtained throughout the entire range of speeds from maximum speed to standstill. Besides less brake wear, resulting in an improved product, the hydraulic drive also has the advantage of requiring a smaller amount of energy for starting and less cooling air to maintain the motor temperature at a low level.

The progress in the production of hydraulically-driven machine tools is now such that the entire operation of the centrifuge battery can be made semi-automatic. Manufacturers are generally able to supply all the individual components required for the development of the hydraulic control system.

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The Bifilar Pendulum for the Damping of Torsional Vibrations

By L. DEVAUX. (From *Revue Universelle des Mines*, 9th Series, Vol. 7, No. 8, August, 1951, pp. 237-250
20 illustrations.)

(*Concluded from December 1951 issue*)

STUDY OF THE PENDULUM-TYPE VIBRATION ABSORBER

The foregoing showed that the elimination of torsional vibrations from a mechanical system is possible by means of a secondary vibrating system having a natural frequency proportional to the exciting frequency. The following lines will refer to the geometry of the pendulum system.

The general theory requires a knowledge of all the characteristics of the main system, in order to determine the damper. Whereas previously the phase angles were considered in relation to the exciting torque, they will now be referred to the motion of the main system. The following study will consider the relative amplitude of the pendulum and its reaction on the main shafting. Furthermore, the significance of the equivalent stiffness k_2 of the pendulum element will be explained.

It will also be shown that this absorber could, in principle, consist of an articulated pendulum connected to the crankshaft, as shown in Fig. 2. This arrangement has disadvantages and it will also be indicated how they have been overcome.

The pendulum acts by means of its inertia. There are two types of pendulum: (a) the pendulum of small mass with large amplitudes of vibration, and (b) the pendulum with a large inertia and small amplitudes of vibration. Only the second type of pendulum will be considered.

Pendulum without damping: We shall consider a crankshaft rotating about its centre O at a mean angular velocity Ω. The tangential effort can be resolved into a series of sine terms with frequencies which are multiples of the basic frequency corresponding to Ω. It will be assumed that it is required to eliminate the vibration of the n–th order, which has an angular velocity $\omega = n\,\Omega$.

A sinusoidal deflection

$$\varphi_1 = \Phi_1 \sin \omega t = \Phi_1 \sin n\,\Omega\,t$$

will be superimposed upon the displacement occurring at the constant mean angular velocity Ω. Referring to Fig. 13, let r_2 = theoretical length of pendulum, and r_1 = distance of centre of rotation A of pendulum from the centre of rotation O of the shaft. Furthermore, let m = mass of pendulum. The pendulum oscillates about A, through a small angle $\varphi_2 = \Phi_2 \sin n\,\Omega\,t$, relatively to the shaft and in phase with φ_1, since the damping is assumed to be zero.

The angle BOA will be denoted by $\epsilon = \varphi_2\, r_2/(r_1 + r_2)$. This assumes that the circular arc of radius AB is equal to the arc of radius OB. The equation of motion can be written by expressing the fact that the tangential component of the inertia force is at any instant in equilibrium with the tangential force produced by the displacement of B. The force of gravity, which is negligible at these speeds, will be omitted.

Furthermore, the Coriolis force, which is orientated along AB, and perpendicular to the plane formed by the axis of rotation O and the direction of relative velocity, does not come into this equation since its projection on the tangent to the relative trajectory is zero. The effect of this force need only be taken into account when calculating the reaction N of the pendulum. The Coriolis force $2\,m\,\Omega\,\varphi_2\,r_2$ is very small for the small amplitudes of vibration and small radii r_2 considered in practice.

The component of the centrifugal force BD is given by

$$-m\,\Omega^2\,(r_1 + r_2)\sin(\varphi_2 - \epsilon) \simeq$$

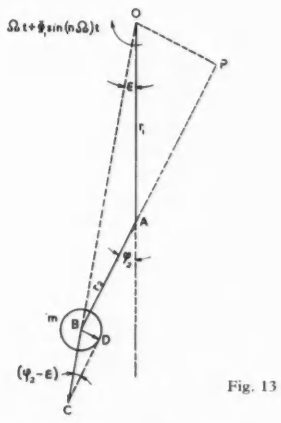

Fig. 13

$$\simeq -m\,\Omega^2\,(r_1 + r_2)\sin\varphi_2 \simeq -m\,\Omega^2\,(r_1 + r_2)\,\varphi_2$$

The tangential displacement of B can be resolved into

an absolute motion: $\varphi_1\,(r_1 + r_2)$,

and a relative motion: $\varphi_2\,r_2$.

The force producing this displacement is

$$m\,[(r_1 + r_2)\,\ddot{\varphi}_1 + r_2\,\ddot{\varphi}_2].$$

The equation of motion can therefore be written as follows:—

$$(r_1 + r_2)\,\ddot{\varphi}_1 + r_2\,\ddot{\varphi}_2 = -\Omega^2\,(r_1 + r_2)\,\varphi_2 \quad (12)$$

after dividing by m throughout. Replacing the second derivatives by their values as functions of $\varphi_1 = \Phi_1 \sin n\,\Omega\,t$ and $\varphi_2 = \Phi_2 \sin n\,\Omega\,t$, we obtain the relation:—

$$\Phi_2/\Phi_1 = n^2\,(r_1 + r_2)/[(r_1 + r_2) - n^2\,r_2] \quad .. \quad (12')$$

which gives Φ_2 as a function of Φ_1.

Neglecting the force due to gravity and the Coriolis force, we take account only of the centrifugal force in obtaining the following expression for the tension P in the arm of the pendulum, which is equal to its reaction on the shaft:—

$$P = m\,\Omega^2\,(r_1 + r_2)\cos(\varphi_2 - \epsilon) \simeq m\,\Omega^2\,(r_1 + r_2).$$

This force acts on a lever arm $OP = r_1 \sin\varphi_2 = r_1\,\varphi_2$. Therefore, the reaction torque is

$$T = P\,r_1\,\varphi_2 = m\,\Omega^2\,(r_1 + r_2)\,r_1\,\varphi_2$$
$$= m\,\Omega^2\,(r_1 + r_2)\,r_1\,(\Phi_2/\Phi_1)\,\Phi_1 \sin n\,\Omega\,t \quad (13)$$

or, taking account of eq. (12) and of the fact that $\omega = n\,\Omega$:

$$T = m\,(r_1 + r_2)^2\,(\omega^2/C)\,\Phi_1 \sin\omega t$$
$$= -(m/C)\,(r_1 + r_2)^2\,\ddot{\varphi}_1 \quad .. \quad .. \quad (14)$$

where $C = [r_1 + r_2\,(1 - n^2)]/r_1$.

If the pendulum is replaced on the shaft by a flywheel with a moment of inertia I_{equiv} giving the same reaction torque: $T = -I_{equiv}\,\ddot{\varphi}_1$, the pendulum can be represented by the equivalent inertia

$$I_{equiv} = m\,(r_1 + r_2)^2/C$$

$$\text{or } I_{equiv} \simeq m\,(r_1 + r_2)^2/[1 - n^2\,(r_2/r_1)] \quad (15)$$

if r_2 is much smaller than r_1.

Thus, according to the harmonic order of the vibration, the pendulum will have an equivalent moment of inertia which will be different in each case, and its effectiveness will vary for this same reason. The maximum value is obtained when

$$1 - n^2 (r_2/r_1) = O, \text{ or } n^2 = r_1/r_2 \quad .. \quad (16)$$

Equation (14) shows, in fact, that for a harmonic order n determined by eq. (16), the vibration amplitude of the main system will be cancelled out. The pendulum is then said to be " tuned " to the order n.

An " overtuned " pendulum ($r_1/r_2 > n^2$) represents a positive moment of inertia. An " undertuned " pendulum ($r_1/r_2 < n^2$) represents a negative moment of inertia. These moments of inertia are greater and more effective as the expression $n^2 r_2/r_1$ approaches unity.

Since for each order n of the disturbance, the pendulum behaves as a flywheel with an inertia varying with n, the series of critical speeds will no longer be proportional to $(1/n)$ as in the classical case. Each order of vibration will correspond to a new natural frequency of the entire system, which can be calculated by taking account of the moment of inertia introduced by the pendulum and given by eq. (15).

Furthermore, if this pendulum is tuned to the n-th order harmonic of the fundamental angular velocity Ω, it will remain tuned to this n-th order regardless of the value of Ω. This is due to the fact that the restoring torque of the pendulum on the shaft is given by eq. (13) as

$$T = m\,\Omega^2 (r_1 + r_2)\, r_1\, \varphi_2$$

and the restoring torque of the pendulum acting on itself is

$$T' = m\,\Omega^2 (r_1 + r_2)\, r_2\, \varphi_2 = k_2\, \varphi_2$$

so that $\quad k_2 = m (r_1 + r_2)\, r_2\, \Omega^2$.

Thus T' is proportional to Ω^2. The natural frequency of the pendulum is proportional to the square root of the restoring torque (k_2), and hence proportional to Ω. In fact,

$$\omega = \sqrt{k_2/I_2} = [m (r_1 + r_2)\, r_2\, \Omega^2/m r_2^2]^{1/2} = \Omega\,[1 + (r_1/r_2)]^{1/2} \simeq \Omega \sqrt{r_1/r_2}.$$

Therefore, the pendulum will remain tuned to the n-th order harmonic, irrespective of the variations of the fundamental frequency.

Pendulum with damping:—The case is more complicated because the movement φ_2 of the pendulum and the disturbance φ_1 are no longer in phase.

The damping in the bifilar pendulum is due to friction of the rollers in their bearings. The friction coefficient being denoted by f, the damping force will be given by

$$D = f P.$$

Experience shows that f increases with the relative velocity of displacement of the lubricated surfaces. The law is non-linear, but can be approximated by a straight line, so that we may write for the damping force the expression

$$D = -\,c\, r_2\, \dot{\varphi}_2$$

$r_2\, \dot{\varphi}_2$ being the relative velocity of the two surfaces.

The pendulum will have a sinusoidal motion of the same radian frequency $\omega = n\,\Omega$ as the disturbance, but with a phase shift β:

$$\varphi_2 = \Phi_2 \sin (\omega t - \beta) \quad .. \quad . \quad (17)$$

where Φ_2 and β are the unknown quantities.

The equation of the relative motion is analogous to eq. (12) but contains an additional term for damping:—

$$(r_1 + r_2)\, \ddot{\varphi}_1 + r_2\, \ddot{\varphi}_2 = -\,\Omega^2 (r_1 + r_2)\, \varphi_2 - (c/m)\, r_2\, \dot{\varphi}_2 \quad (18)$$

The solution is given by

$$\tan \beta = c\, r_2\, n/[m\,\Omega\,(r_1 + r_2 - n^2 r_2)] \quad (19a)$$

$$\Phi_2/\Phi_1 = (r_1 + r_2)\, n^2/[(r_1 + r_2 - n^2 r_2)^2 + (c\, n\, r_2/m\,\Omega)^2]^{1/2} \quad .. \quad .. \quad .. \quad (19b)$$

The reaction torque of the pendulum on the shaft is

$$T_r = m\,\Omega^2 (r_1 + r_2)\, r_1\, \varphi_2 + c\, r_2 (r_1 + r_2)\, \dot{\varphi}_2.$$

As $\dot{\varphi}_2$ is not in phase with φ_2, T_r will also be out of phase with φ_2, so that it will be an expression of the form

$$T_r = T_1 \sin (\omega t + \delta - \beta) \quad .. \quad (20)$$

The values of δ and T_1 are obtained by replacing φ_2 and $\dot{\varphi}_2$ by their values derived from eqs. (17) and (18) and neglecting r_2 relatively to r_1. This gives

$$\tan \delta = c\, n\, r_2/(m\,\Omega\, r_1) \quad .. \quad .. \quad (21a)$$

and $\quad T_1 = m (r_1 + r_2)^2\, [(Q^2 + R^2)/(Q^2 + R\,C')]^{1/2}$ (21b)

where $Q = c\, n\, r_2$, $R = m\,\Omega\, r_1$, and $C' = 1 - (r_2\, n^2/r_1)$.

The damped pendulum can thus no longer be assimilated to a simple flywheel. To obtain a clearer idea of the phenomenon, it will be convenient to write the equation of motion of the disc carrying the pendulum. We consider the following simple case (Fig. 14):—A disc of moment of inertia I_1 is coupled to a

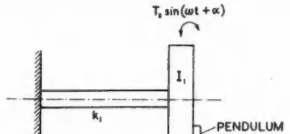

Fig. 14

flywheel with an infinite moment of inertia by means of a shaft of stiffness k_1. The disc carries the pendulum which has been considered and is subjected to an exciting torque $T_s \sin (\omega t + \alpha)$, for which T_s and α are such that the resultant motion of the disc is $\varphi_1 = \Phi_1 \sin \omega t$.

The phase angle α between the exciting torque and the motion of the main system is due to the damping occurring in the main system and the pendulum. The equation of motion is written as follows:—

$$I_1\, \ddot{\varphi}_1 + k_1\, \varphi_1 = T_s \sin (\omega t + \alpha) + T_1 \sin (\omega t - \beta + \delta) \quad .. \quad .. \quad (22)$$

Replacing $\ddot{\varphi}_1$ and φ_1 by their values as functions of $\varphi_1 = \Phi_1 \sin \omega t$ and dividing by $\Phi_1 k_1$, we have the two unknowns

$$(1/M) = T_s/(\Phi_1 k_1)$$

and α, since T_1, β and δ are determined by means of the eqs. (21b), (19a) and (21a), and $\omega_1^2 = k_1/I_1$.

The solution gives the following values:—

$$\tan \alpha = (T_1/\Phi_1 k_1) \sin (\delta - \beta) \Big/ \left\{ [1 - (\omega/\omega_1)^2] - (T_1/\Phi_1 k_1) \cos (\delta - \beta) \right\} \quad .. \quad (23a)$$

$$1/M^2 = G_2^2 + \mu^2 F_1^4 (4\gamma^2 + 1)/(4\gamma^2 + G_2^2) + 2\, G_1\, \mu\, F_1^2 (\gamma^2 + G_2)/(4\gamma^2 + G_2^2) \quad .. \quad (23b)$$

where $G_1 = 1 - F_1^2$ and $G_2 = 1 - F_2^2$, the other non-dimensional quantities being defined as previously.

The three diagrams of Figs. 15-17 correspond to three values of the frequency ratio F_2. In each case, this tuning ratio is constant, which means that n remains constant in the given system. The curves of M are plotted against the frequency ratio $F_1 = \omega/\omega_1 = n\,\Omega/\omega_1$, where only Ω varies. The diagrams thus illustrate the effect of the pendulum for all running speeds and for a given order of vibration.

Tuned pendulum (Fig. 15):—When the pendulum damping is zero, the vibration amplitude of the main system is zero for the n-th order regardless of the velocity Ω. It is therefore important, in the practical

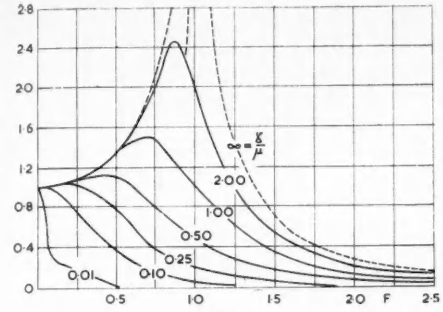

Fig. 15

design of the pendulum, to reduce its damping as much as possible. With increasing damping, a series of curves is obtained, the uppermost being the resonance curve for infinite damping ($\gamma = \infty$). In this latter case, the pendulum has no relative motion but increases only the total inertia by its own inertia, $m\,(r_1 + r_2)^2$, so that the natural radian frequency of the entire system is slightly lower than ω_1; its value is then:

$$\omega_1' = \omega_1 \sqrt{I_1/[I_1 + m\,(r_1 + r_2)^2]}.$$

Moreover, if $F_2 = 1$ (or $G = 0$), the third term of eq. (23b) is independent of the damping γ, which only affects the second term.

In practice, $\mu < 0{\cdot}1$, and $\Phi_1/(T_s/k_1)$ is mainly affected by the ratio γ/μ. Therefore, in the case of a fully-tuned absorber, if this latter ratio is maintained constant while increasing the values of γ and μ, the behaviour of the main system as regards vibrations will remain unchanged.

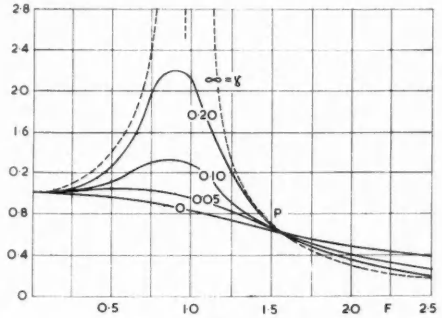

Fig. 16

Undertuned pendulum (Fig. 16): In this case $F_2 > 1$ or $G < 0$. In the example given, $G = -0{\cdot}08$. Neglecting damping, the pendulum is equivalent to $-1/0{\cdot}08 = -12{\cdot}5$ times its own moment of inertia. For a form factor $\mu = 0{\cdot}1$, the pendulum has an equivalent inertia equal to $-1{\cdot}25$ times that of the main system. Thus, the moment of inertia of the entire system is $(1 - 1{\cdot}25)\,I_1 = -0{\cdot}25\,I_1$.

Equation (23a) then reduces to: $\Phi_1/(T_s/k_1) = 1/(1 + 0{\cdot}25\,F_1^2)$. There is no resonance effect, because the denominator is never zero.

Overtuned pendulum (Fig. 17): $F_2 < 1$ and $G > 0$. In the example given, $G = 0{\cdot}08$ and $\mu = 0{\cdot}1$. The apparent inertia of the pendulum without damping is $2{\cdot}25 I_1$, which leads to a curve with resonance at the frequency ratio $F = 1/\sqrt{2{\cdot}25}$. When damping is infinite, the pendulum is rigidly fixed to the main system, which gives the resonance curve at $F = 1/\sqrt{1{\cdot}1}$. In Figs. 16 and 17, the curves pass through the same

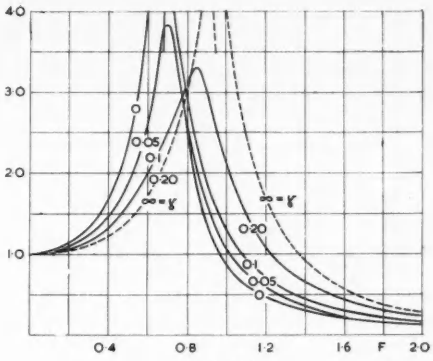

Fig. 17

point P. The abscissa of P is obtained by equating to zero the derivative of the amplitude with respect to damping. This gives:

$$F_1^2 = 2\,G_2/[\mu\,(1 + G_2) + 2\,G_2].$$

CONCLUSIONS

In practical applications, a pendulum with a low amplitude of vibration must have a considerable mass. The larger this mass is, the more effective the absorber will be.

For a simply suspended pendulum, it is not permissible to assume that the mass is concentrated at a single point. The pendulum frequency is no longer $\omega = \Omega \sqrt{1 + (r_1/r_2)}$, but is determined by

$$\omega = \Omega \sqrt{m\,(r_1 + r_2)\,r_2/I_2} = \Omega \sqrt{m\,(r_1 + r_2)\,r_2/(m\,\rho^2{}_2)}$$

A large mass corresponds to a large radius of gyration ρ_2. Let us assume that it is required to tune the pendulum to the n-th order harmonic of the crankshaft angualr velocity Ω. The exciting frequency is then $\omega = n\,\Omega$, and the pendulum dimensions must be such that they will satisfy the equation

$$n = \sqrt{(r_1 + r_2)\,r_2/\rho_2{}^2}.$$

This means that a very small radius of gyration is required for harmonics of higher order. Although the pendulum mass, which must be appreciable, can be divided into a large number of pendulum units with a small ρ_2-value, this solution is cumbersome and complicated.

The Sarazin pendulum with a bifilar suspension (Fig. 2) overcomes this difficulty in regard to the moment of inertia. The system is designed in such a way that all the points of the pendulum swing through circular arcs of equal radius. The mass can, therefore, have any required value and its natural frequency is independent of the moment of inertia. The suspension is by means of two rollers of raidus r', which move in cylindrical races of radius r''. This arrangement has the following advantages:—

1. The radius of the oscillatory motion is $r_2 = 2\,(r' - r'')$. By using suitable values for r' and r'', the radius r_2 can be made as small as is required for tuning the pendulum to any harmonic order, in accordance with the relation

$$n = \sqrt{1 + r_1/2\,(r' - r'')}$$

where $r_1 = R - 2\,(r' - r'')$, R being the distance of the centre of gravity of the pendulum mass from the shaft centre.

2. The roller arrangement reduces frictional damping to a minimum value. It thus gives a closer approximation to the ideal case, for which $\gamma_2 = 0$.*

*The bifilar suspension and the roller arrangement are covered by patents.

3. The bifilar pendulum makes it possible to eliminate critical speeds by reducing vibration amplitudes with practically no dissipation of energy, which is not the case with the Lanchester type damper.

4. The pendulum operates without trouble due to wear, and no special maintenance is required.

5. A single pendulum will eliminate completely one order of vibration and also reduce the effect of vibrations of neighbouring orders.

This latter effect can be explained as follows:— For simplicity, we shall consider the pendulum without damping. If it is tuned to the n-th order, r_1 and r_2 will satisfy the relation $n^2 = r_1/r_2$ and the equivalent pendulum inertia is infinitely large. For an adjacent order n', the difference $1 - n^2\, r_2/r_1$ is small, so that the equivalent inertia of the pendulum will still have a very large value. This corresponds to the case shown in Fig. 16 if $1 - n^2\, r_2/r_1 < 0$, or to the case of Fig. 17 if $1 - n^2\, r_2/r_1 > 0$. Thus, for example, an absorber system with four pendulum elements can practically eliminate all orders of vibration within the running range.

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GERMANY

Energy Losses in Steam Pipes due to Pressure Drop

By M. LANG. (From *Brennstoff-Wärme-Kraft*, Vol. 3, No. 9, September 1951, pp. 301-303, 4 illustrations.)

The pressure drop caused by throttling devices, boiler fittings and piping is normally so small that it cannot be accurately represented on the enthalpy-entropy chart. A procedure is described whereby the energy losses due to pressure drop can be established. A practical example shows that small losses of pressure can already cause an appreciable energy loss.

Description of Method.

A pressure drop, caused by a throttling device such as a boiler fitting, will increase the entropy of the steam. During expansion, this increase in entropy manifests itself as an energy loss which can, in principle, be evaluated from the enthalpy-entropy chart. In practice, however, at the usual working pressures, the corresponding distances in the diagram are unrecognisably small. The principle of the method which overcomes this difficulty is given in the following.

Let us assume the following steam condition: live steam $p_1 = 39$ atmospheres, $t_1 = 430$ C corresponding to an enthalpy of $i_1 = 783{\cdot}8$ kcal/kg and an entropy of $s_1 = 1{\cdot}6449$ kcal/kg °C. The steam is expanded to $p_1 = 6$ atm with a thermodynamic efficiency of 0·645, giving an effective heat drop of 72·9 kcal/kg. Let Δ represent a large difference of values and ∂ represent small changes of state which may be considered linear.

The total change in enthalpy can be written as

$$\partial i = \left(\frac{\Delta i}{\Delta p}\right)_T \partial p + \left(\frac{\Delta i}{\Delta T}\right)_p \partial T \quad \ldots \quad (1)$$

For the graphical representation (Fig. 1) the values chosen are $\Delta p = 50 - 30 = 20$ atm. Projecting along the isothermal curve $t_1 = 430$ C, we find $\Delta i = -6{\cdot}0$ kcal/kg. Thus,

$$\left(\frac{\Delta i}{\Delta p}\right)_T = \frac{-6{\cdot}0}{+20} = -0{\cdot}30 \quad \ldots \quad (2)$$

Again, for a chosen value of $\Delta T = (450—400)$ C $= +50$ C, we project along the isobar $p_1 = 39$ atm: $\Delta i = +27$ kcal/kg and, therefore,

$$\left(\frac{\Delta i}{\Delta T}\right)_p = \frac{+27}{+50} = +0{\cdot}54 \quad \ldots \quad (3)$$

Substituting these two values into eq. (1), we obtain

$$\partial i = -0{\cdot}30\, \partial p + 0{\cdot}54\, \partial T \quad \ldots \quad (4)$$

This equation can be used to calculate enthalpy changes as a function of temperature and pressure

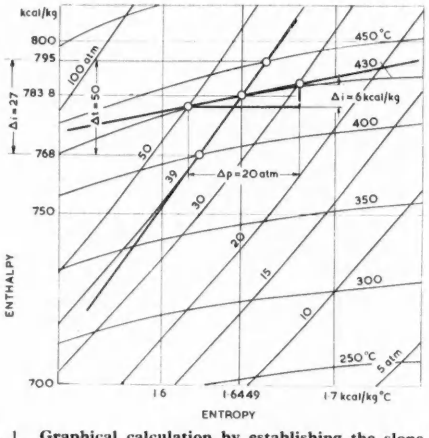


Fig. 1. **Graphical calculation by establishing the slope of isobars and isothermal curves in the enthalpy-entropy diagram.**

change. Naturally, it is valid only in the above units and for the above steam conditions. Its accuracy is limited to the range over which the curves may be assumed to be linear, but it is very accurate for small changes.

Throttling on the inlet side of a back-pressure turbine.

As an example, the method will be applied to the calculation of losses resulting from the introduction, on the inlet side, of a measuring diaphragm. With a maximum steam flow of 85 tons/hr the pressure drop across the diaphragm is 6 m water column. The pointer lies at a position 2/3 along the scale, so that the effective pressure drop is only $(2/3)^2 \times 6 = 2{\cdot}67$ m water column. The orifice ratio of the diaphragm is taken as 0·45, causing a permanent pressure drop of

$(1 - 0{\cdot}45) \times 2{\cdot}67 = 1{\cdot}47$ m water column .. (5)

Through throttling, a loss of heat drop results. To calculate this, a larger pressure drop of, for instance, $\Delta p = 4$ atm is assumed, represented in Fig. 2 by AA', to which corresponds an increase in enthalpy of $\Delta i = 3{\cdot}6$ kcal/kg along BB' on the back pressure isobar $p = 6$ atm. The change of enthalpy of the back-pressure steam with respect to the pressure drop of live steam is, therefore,

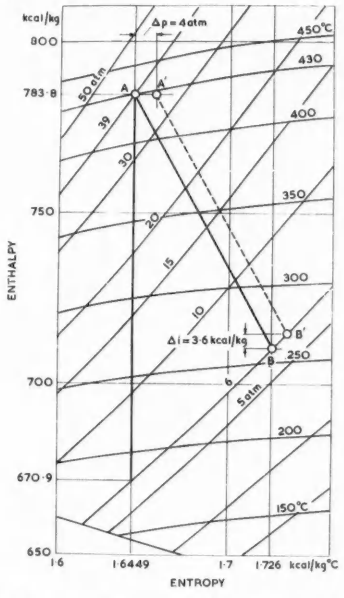


Fig. 2. **Representation of a throttling process on the inlet side of a back-pressure turbine.**

$$\frac{\Delta i}{\Delta p} = \frac{3{\cdot}6}{4} \quad .. \quad .. \quad (6)$$

so that $$\partial i = 0{\cdot}9\ \partial p \quad .. \quad .. \quad (7)$$

From this, for a permanent pressure drop of 1·47 m, we have $\partial i = 0{\cdot}9 \times 0{\cdot}147 = 0{\cdot}132$ kcal/kg.

The diaphragm thus causes a heat loss of 0·132 kcal/kg, representing a loss of 0·18 per cent of the total heat drop of 72·9 kcal/kg.

Assuming an overall mechanical efficiency in generation and distribution of 0·9 and an annual run of 7200 hours, the steam consumption is 85,000 kg/hr $\times$ 7200 hr/year $= 610 \times 10^6$ kg/year, representing a loss of electrical energy of

$$\frac{(610 \times 10^6\ \text{kg/year}) \times (0{\cdot}132\ \text{kcal/kg}) \times 0{\cdot}9}{860\ \text{kcal/kWh}} = 84{,}000\ \text{kWh/yr}$$

The loss in heat drop due to throttling which could have been utilised for energy production reappears as heat in the exhaust steam. Its thermal value, however, is less than its equivalent in energy lost. To establish a relation between the value of energy in the form of available heat drop and in the form of heat in the exhaust steam, the author introduces the concept of "energy index." Taking this figure as 4·2*, the actual loss of energy is reduced by the factor $(1 - 1/4{\cdot}2) = 0{\cdot}762$.

The replacement of the measuring diaphragm by a Venturi meter is suggested. This causes a pressure drop of only 1/3 of the diaphragm at the same orifice ratio.

Throttling on the exhaust side.

For the same amount of throttling on the exhaust side of the turbine, the values obtained are: $\Delta i = 11$ kcal/kg, $\Delta p = 2$ atm, $\partial i = 5{\cdot}5\ \partial p$. Comparing this with eq. (7), we see that the relative loss has increased from 0·9 to 5·5, i.e., more than sixfold. As it is not always possible to reduce the pressure drop across the diaphragm to one-sixth, the above considerations suggest that flow measurements should be carried out, whenever possible, on the inlet side of the turbine.

*M. Lang: "Das Industrie Kraftwerk," Leipzig 1949, pp. 11-13.

U. S. A.

Increase of Generator Ratings by Internally Cooled Coils

By C. M. LAFFOON. (From *Electrical Engineering*, Vol. 70, No. 11, November 1951, pp. 1013-1015, 3 illustrations.)

A RADICALLY new method of cooling large turbo-generators greatly increases the ratings in which these high-speed machines can be built. The basis of the new ventilation technique is to cool the active conductors internally by making them hollow and blowing hydrogen gas at high velocities through them, thus placing the coolant in intimate contact with the material in which the heat is generated. At present, one 175,000-kW and one 200,000-kW generator, both designed for 3,600 rpm, are being built with rotor windings having internal cooling; another generator, with a capacity of 90,000 kW and a speed of 3,600 rpm, using internally cooled rotor as well as stator windings, is expected to be available for testing in 1952.

To keep pace with the growing demand for larger generating sets, designers had in the past to rely on incremental improvements in the physical, electrical and thermal properties of steel, copper and insulation to reduce the generator weight per unit of capacity. However, to secure a major reduction, some radically new feature was needed. During recent years, much attention has been given to the possibility of using unconventional cooling media to achieve this aim, but as yet none of these schemes has proved practical. The answer to a substantial improvement is believed to lie in internal cooling of rotor and stator windings with high-density hydrogen. This offers possibilities of increasing the amount of copper losses that can be dissipated for a given maximum temperature rise. With the heat flow through the insulation of the windings almost completely eliminated, the temperature of the windings is determined by the temperature of the hydrogen gas in contact with the copper and by the heat transfer coefficient from the copper to the gas.

The curves in Fig. 1 show the rotor ampere conductors per slot obtainable from tests on a full-size stationary model, with the average and copper temperature maintained the same for the two types of construction. The lower curve relates to the conventional rotor design with external cooling, and shows that further increase in hydrogen pressure will offer very little increase of rotor ampere conductors. On the other hand, the benefit obtained with hollow conductors is much higher. The increase is extremely high at the higher gas pressures.

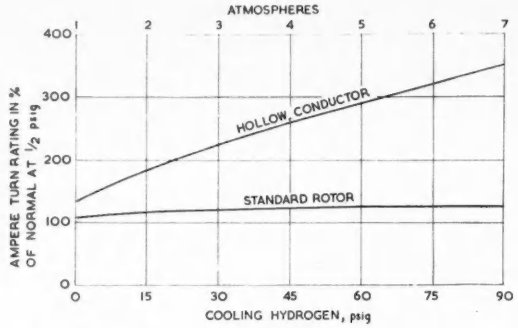


Fig. 1. **Effect of hydrogen pressure on ampere-turn rating for hollow conductors and standard rotor.**

The high increase in ampere conductor output for the internally cooled rotor winding is obtained by passing large masses of hydrogen gas through internal passages of the conductors at relatively high velocities. It is therefore obvious that the full advantage of inner cooling is basically associated with high hydrogen pressures and requires use of high-pressure blowers to circulate the gas through the internal ducts. In this type of rotor the conductors are necessarily of large cross-section and few in number. With the rotor ampere conductors greatly increased by internal cooling, the field current is large, the field voltage relatively low, and the excitation input approximately twice that for a rotor of a generator of conventional design. Rotating coil models of large size have been built and tested to demonstrate that internal blowers mounted on ends of the rotor can deliver the required mass of hydrogen through the rotor conductors.

Similar benefit can result from internally cooling the stator coils. The insulation problem is more difficult in the case of stator coils because of the higher voltage involved and the need for creepage paths of greater length over that required for the rotor. With machines in which the cooling can be accomplished by passing the hydrogen gas through the full length of the coils, the creepage problems are relatively simple and no difficult mechanical and ventilation problems are involved. In the longer machines, in which a central hydrogen discharge is required, the creepage problems are more difficult but do not appear to be unsolvable.

The curves of Fig. 2 show what can be expected of internally cooled rotor windings and both rotor and stator windings, as compared with conventional designs. The kilowatt ratings are based on 0·85 power factor, 0·8 short-circuit ratio, and operation at 30 psig hydrogen pressure. From a magnetic standpoint, no changes have been made in flux densities in the stator and rotor portions of the magnetic circuit. In comparing the physical dimensions of a 200,000-kW unit for the two types of design, the size factor for the rotor with inner cooling of the conductors is only 62 per cent of that in the case of the conventional rotor. The reduction in stator dimensions is of smaller magnitude, since internal cooling of the stator conductors is not used. In the case of internal cooling for both stator and rotor windings, the rotor size factor is only 50 per cent of that for the conventional machine of the same rating and performance characteristics ; a similar reduction in the size factor for the stator also would be obtained.

The development of internal cooling with high-pressure hydrogen gas opens up a new era in the design and construction of turbo-generators without too great a departure from present practice and experience. The increased output per unit of generator weight makes possible smaller units for a given rating and appreciably larger maximum rating at 3,600 rpm than were hitherto obtainable with conventional designs. The overall efficiency including generator bearing losses, then, will be essentially the same as in the case of units of present conventional designs. The increase in copper losses of the stator and rotor windings due to higher current densities is more than offset by the reduction in bearing losses resulting from the smaller bearings required for the smaller rotors, and the reduction in rotor surface losses resulting from the appreciable increase in the radial length of the air gap and the decrease in rotor surface area. The increase in ventilation loss due to higher fan pressures is partially offset by the reduction in the volume of gas to be delivered by the blowers. For turbo-generators with internal cooling of the conductors, the excitation and terminal voltages are lower than for similar ratings of conventional design because of the mechanical requirement of larger overall section for the rotor conductors and the inherent limitations in insulation surface creepage at the inlet and discharge sections of the conductors for both windings.

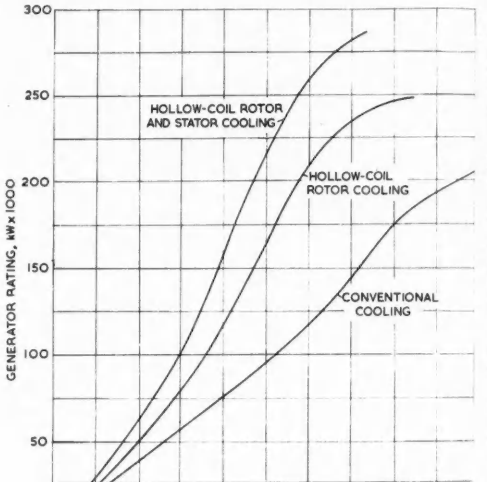


Fig. 2. **Graph showing how internal cooling affects generator rating.**

Internal cooling of the rotor and stator windings of turbine generators with high-density hydrogen is particularly applicable to units for ratings of 90,000 kW and higher. The improved cooling makes possible ratings much larger than obtainable with conventional gas cooling. Although the saving in cost resulting from the use of less material are more than offset at the present state of development by the large development costs required, large capacity turbo-generator units of this type, even at present unit costs, should result in lower overall station capital and operating costs without any sacrifice in efficiency performance.

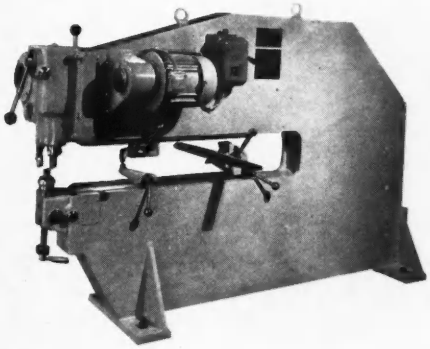
A generator of 60,000 kW capacity incorporating this new cooling system is already in operation at Edgwater Power Station in the U.S.A. The voltage generated is 12,500 V at 3600 rpm, and it is claimed that the constructional materials employed were only 60 to 70 per cent of those normally used in generators of this size. This reduction in size, while important in itself, leads to an overall reduction in the size of power station buildings, with consequent economies in the cost of the property. The new design also brings about a substantial increase in the short-circuit reactance, which allows additional savings in the cost of circuit breakers, reactors, and other power station equipment.—Editor, E. D.

New Materials, Processes and Equipment

IMPROVED "PULLMAX" MACHINE

The American Pullmax Company, Inc. announces the new, improved 9/32 in. capacity Pullmax machine, Model D-3. This new machine has an increased throat clearance which makes for easier inserting and handling of bulky material.

Due to this increase in clearance, the machine is equipped with longer cutting tools which will give longer life to the tools. The machine also features quick-locking devices on both the circle and straight cutting attachments. This feature enables the operator to set up much faster as no tools or wrenches are required. The lower guide rail is graduated in inches, which also helps speed the setting-up time when cutting circles or squares.



The frame of the machine is of box-type construction made of welded steel plate. All moving parts are enclosed and operate in an oil bath. Throat depth is 48 in. for clearance of large steel sheets.

TESTING OF CORROSION IN WIRE ROPES

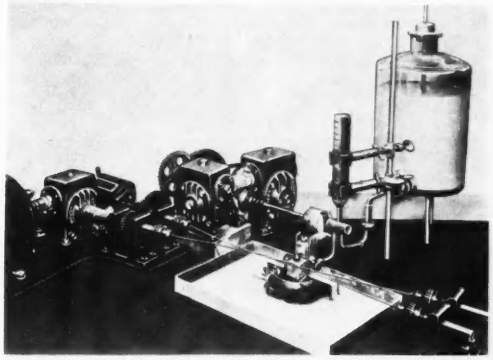
An interesting series of laboratory tests has recently been carried out by Anglo-Transvaal Consolidated Investment Co. Ltd. as part of a general investigation of underground corrosion in South African gold mines. This particular apparatus was used to measure the nature and extent of corrosion in wire ropes and to test the effectiveness of various types of lubricants in checking this deterioration.

Main items of apparatus used were a driving motor, a revolution counter, three David Brown Radicon worm reducers, a Marriotte bottle containing a brine solution, an atomiser controlling air supply, and two test wires.

For the purpose of the experiment the two wires were rotated about their own axes in opposite directions and at different speeds (37 rpm and 20 rpm). This was achieved by transmitting the main drive through a $1\frac{1}{8}$ in. (40 : 1 ratio) Radicon reducer and a set of spur gearing to two chucks in which the ends of the wires were held.

Rotation of these chucks induced high unit pressures between the wires, thus reproducing the rubbing together of individual strands of wire with continual breaking and repairing of the oil film, as experienced under actual working conditions.

Also connected to the main drive through a set of intermediate spur gears were two more small Radicon

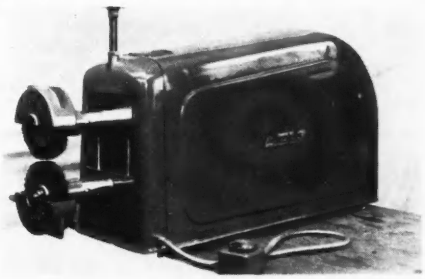


worm reducers, a $1\frac{5}{8}$ in. (20 : 1 ratio) unit and a second $1\frac{1}{8}$ in. unit, in this case of 50 : 1 ratio.

Reduction of the drive from the second of these two inter-connected Radicons was carried a stage further by another set of gearing to achieve a very slow final drive to the brine supply cock, which was required to rotate only once every 50 minutes. During this time a measured quantity of 20 per cent brine solution, equivalent to the high saline content of water encountered in South African mines, was sprayed over the wires for three minutes, while air was directed on the wires continuously from an atomiser nozzle.

NEW TWIN HEAD BRUSHING MACHINE

This new model by B. O. Morris Ltd., Coventry, is available in two versions. One gives a projection for centre line of brushes to front of casing of 4 in., and the other of 14 in. Both of these models have otherwise the same characteristics.

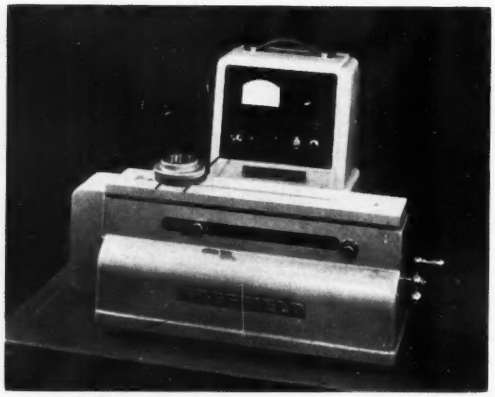


Any diameter of brushes ($\frac{3}{8}$ in. or $\frac{1}{2}$ in.) from 3 in. up to 6 in. can be used. Any width of brush up to 2 in. (when using the appropriate adaptor) can be accommodated. The top brush is mounted on a spindle which is adjustable vertically by a screw feed and locking nut to give any distance between the brush peripheries up to $\frac{3}{8}$ in. The machine is operated by means of a foot switch on which pressure must be maintained for continuous running. Release of pressure will automatically stop the machine. Inside the machine is another switch which is fitted with thermal overload trips to cut out the machine if overheating occurs.

The machine is designed so that the brushes retain the workpiece for the guidance of the operator, and there is no tendency for the workpiece to be pulled into the brush.

ELECTRONIC GAUGING HEAD

A new remote electronic gauging head is now being supplied with their N-6 " Internalchek " instrument, according to an announcement by The Sheffield Corporation of Dayton 1, Ohio. Standard dual amplifications are 1,000/2,000, 300/3,000, 5,000/10,000 to 1. Other amplifications are available on special order. This instrument is normally used in the tool room or gauge laboratory, for checking master and working ring gauges, setting snap and length gauges, for checking tools and other high-precision work having one or more internal dimensions. Precision blocks or masters are used as a reference in setting up the instrument. Both bench type and console base are available.



The Sheffield electronic gauge head consists primarily of a highly stabilized a.c. vacuum tube circuit which gives indication on a high-speed meter. A built-in regulating transformer controls fluctuations of 95-125 volts to within 1 per cent, assuring extra long life of tubes. The elimination of drift in the circuit permits accurate measurements continuously or intermittently, over long periods of time without constant resetting. The scale is linear both sides of zero.

The instrument has a wide gauging range from a min. dia. of 0·370 in. to a max. dia. of 12 in. Maximum gauging depth from surface plate to centre of diamond point is 1½ in. By turning the part over, another 1½ in. depth of the hole may be checked, making it possible to explore a hole 3 in. deep throughout for diameter, taper, bell mouth, and out-of-round conditions.

HEAVY-DUTY STAPLING GUN

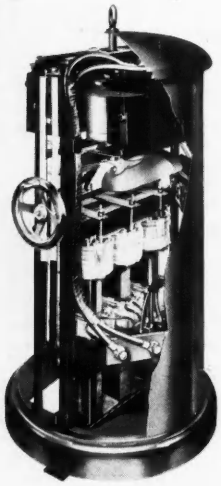
A handy new pocket-sized stapling gun that packs five times the power of ordinary one-hand industrial tackers has been developed by The Heller Company of Cleveland, Ohio.

This tool is the first one-hand stapler capable of fastening metal or fibre shipping tags to export boxes. It saves time and manpower for the shipper, fastening tags in one-fifth the time needed for hammer and nails.

The stapling gun can also be used for stapling shipping list protectors, lining of export boxes, fibre packing list covers, railroad box car linings, car identification tags and many other operations where speed and secure fastenings are needed.

D.C. WELDING MACHINE

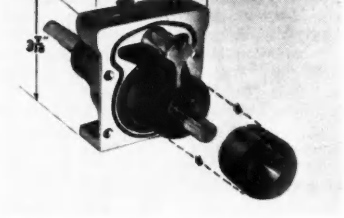
A new heavy-duty direct current welding machine has been put on the market by the A. O. Smith Corp., Milwaukee, Wis. Extensive field testing has shown the new unit to be free of stack failure. This is accomplished by directing a high-velocity downdraught of cool air over the rectifier stacks before passing this air through other parts of the machine. The blast is expelled at the base of the welder. This not only assures proper cooling, but promotes internal machine cleanliness.



Among the principal features are the case-diameter fan and " wind tunnel " design to assure adequate, efficient air flow over all energized parts. The primary coils are raised and lowered easily on ball bearing jacks. The machine is available in 200, 300 and 400 ampere ratings.

TEFLON IMPELLERS IN STAINLESS STEEL PUMP

A radically new line of Chemical Process Pumps has been announced by Eco Engineering Co., Newak 1, New Jersey. As standard equipment, they have Teflon impellers, a Teflon-packed stuffing box and a choice of Teflon or Graphitar self-lubricating bearings. Manufactured with stainless steel pump casings and shafts, these compact pumps are used for small volume process or laboratory work. They operate in either direction in capacities from 1 to 20 U.S. gpm and pressures up to 40 psi with excellent lift.



Because Du Pont Teflon is chemically and biologically inert and is entirely unaffected by any acid, organic solvent or alkali solution, the problem of choosing the right pump for a given job is geatly reduced.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ENAMELLED PRODUCTS

De-Enamelling Process

By K. ROSE. (From *Materials & Methods, U.S.A.*, Vol. 34, No. 5, November, 1951, pp. 80-81, 4 illustrations.)

WHEN finishing ironware with a coating of vitreous enamel, the difficulty of reclaiming defective pieces by removing the coating and re-finishing is much more difficult than with most other surface finishes.

The de-enamelling process described in this article consists of stripping the enamel in a hot caustic soda solution, rinsing, and cleaning the metal surface mechanically by sandblasting. Handling of the pieces is facilitated by conveyors which move the work through the rinsing units and the sandblast rooms.

An essential condition for economical operation of a de-enamelling plant is volume of production. Operation of a de-enamelling process for only a few hours a week, as might be required by a single enamelling plant, is costly, whereas a commercial plant taking the defective pieces from many enamellers can be operated full-time. Refinements in the process and the present high cost of steel have helped to make the operation economically successful.

FOUNDRY PRACTICE

Impregnation Methods Reduce Casting Costs

By M. JORDAN NATHASON. (From *Steel, U.S.A.*, Vol. 129, No. 23, December 3, 1951, pp. 88-89, 110, 3 illustrations.)

FEW problems in the metal industry are more disconcerting than lost production and delivery lag caused by porosity rejects in castings designed to be pressure-tight. To be acceptable, they are usually pressure-tested to at least 50 per cent higher than the expected operating pressure.

With the introduction and growing acceptance of low-density metals, several thermosetting resins came into being. Most widely used as a salvage medium were phenolic and styrene resins mixed with linseed and castor oils. Their greatest disadvantage lies in the fact that they are not 100 per cent solids. " Bleeding out " during curing operation often makes several impregnations necessary because of the presence of a large quantity of volatile constitutents.

The ever-existing loss due to porosity led to a search for fast, easily applied sealants capable of meeting the highest industrial requirements. Resistance to higher pressures and wider ranges of temperatures as well as solvents, chemicals, acids, alkalies, and fuels has become increasingly more important. One such sealant contains 100 per cent solids, is a thermosetting copolymer capable of withstanding extreme pressures and temperatures and does not react with industrial liquids and gases. Treated parts show no discoloration, change in critical tolerance, or other visible signs of impregnation. It is applicable to ferrous as well as to all non-ferrous metals.

Operational steps required to complete the impregnation cycle in the autoclave are : (1) Evacuation, which removes all entrapped air from the pores in the metal casting wall ; (2) introduction of sealant into the evacuated pores ; (3) neutralisation of air in the autoclave ; (4) pressure application which exerts equal force to all sides of the metal wall ; (5) removal of sealant. Capillary action keeps the sealant in the pores during rinsing and cleaning of casting, prior to curing operation.

HEAT TREATMENT

Hot Oil Quenching Expands Use of Carbon Steels

By J. H. GREENE. (From *Steel, U.S.A.*, Vol. 129, No. 14, October 1, 1951, pp. 64-67, 3 illustrations.)

HOT oil quenching, compared with conventional quenching, requires more equipment, greater safety precautions, cleaning of the work during the latter stages of oil life, and is limited with respect to the size, shape, and types of steel which can be quenched to full hardness. Unless distortion or residual stresses constitute problems, it may not be desirable to use a hot oil quench.

The process is, however, applicable to a wide range of important steels. For the many cases in which satisfactory hardness can be obtained, it gives improved control of dimensional changes by reducing or eliminating distortion ; increased service life and load-carrying capacity of the parts result from reduced residual stresses.

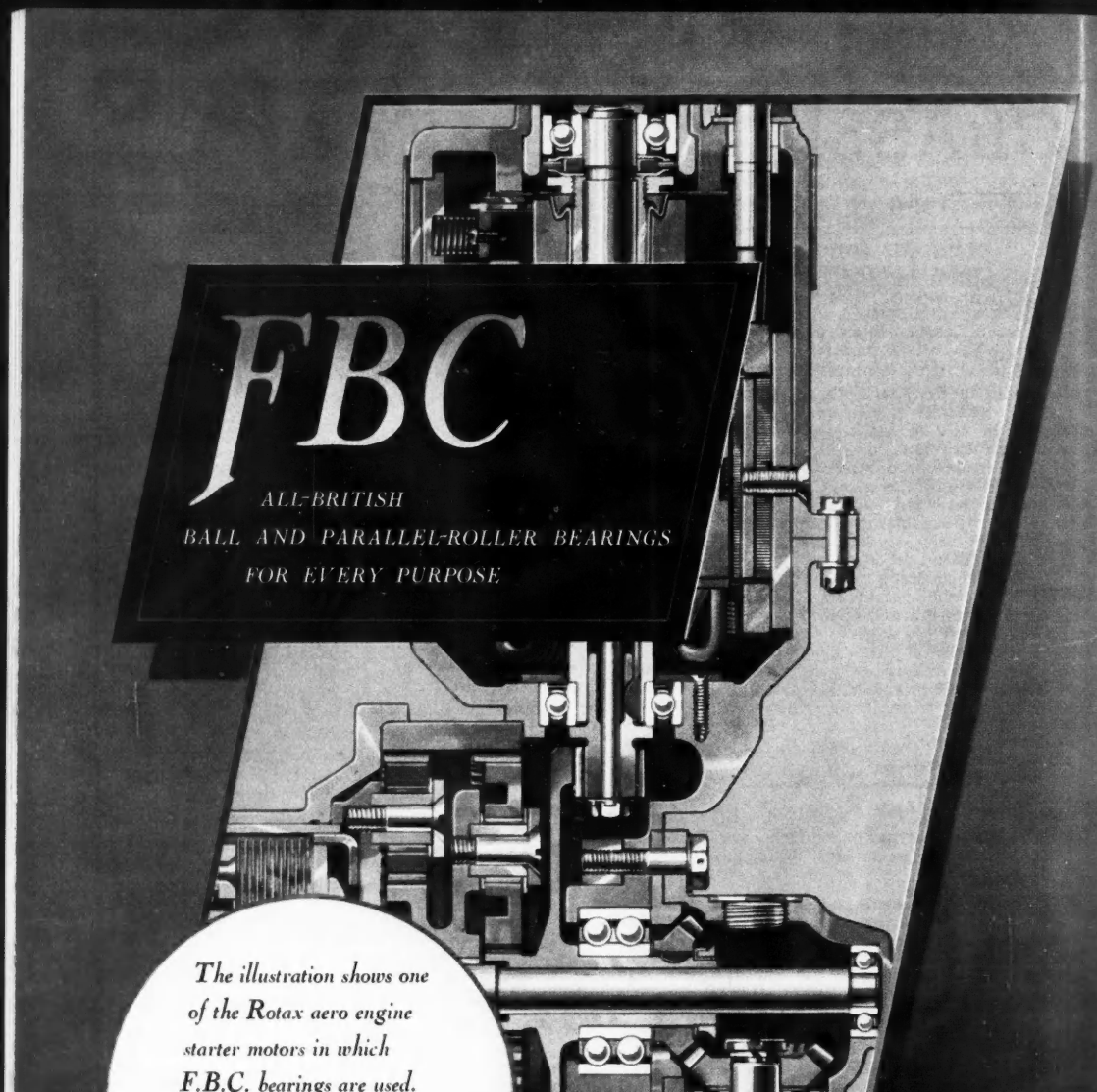
In large-scale production, hot oil quenching greatly increases the output per furnace. This is due to the elimination or reduction of finishing operations, large reductions in rejects, and to expediting subsequent assembly. Reduced tolerances before hot quenching may also be possible.

ILLUMINATING ENGINEERING

A New High-Pressure Mercury Lamp with Fluorescent Bulb

By J. L. OUTWELTJES, W. ELENBAAS, and K. R. LABBERTÉ. (From *Philips Technical Review, Holland*, Vol. 13, No. 5, November, 1951, pp. 110-118, 9 illustrations.)

THE high-pressure mercury lamp (HP) has a very good specific light yield, viz, 35 to 40 lm/W, but the colour rendering under the light of this lamp is poor, mainly due to a deficit in the red. The colour rendering can be greatly improved by converting the useless ultra-violet radiation from the mercury discharge into red light by means of a fluorescent substance. For the HPL lamp developed on this principle, the fluorescent substance first used was zinc cadmium sulphide activated with copper. Upon excitation with the ultra-violet rays this substance shows an orange-red fluorescence with a reasonable quantum efficiency, it retains its fluorescence also at the temperature of about 150° C to which it is exposed when applied to the inside of the bulb of an HP lamp, and while the lamp is alight this substance undergoes only a very gradual dissociation. A drawback, however, is that it absorbs the blue, so that the resultant colour rendering is nevertheless unsatisfactory. After a number of unsuccessful attempts to find more suitable phosphors, a very good solution has now been reached by employing magnesium arsenate activated with quadrivalent manganese. The quantum efficiency of this bright-red fluorescing phosphor is even appreciably


FBC
ALL-BRITISH
BALL AND PARALLEL-ROLLER BEARINGS
FOR EVERY PURPOSE
The illustration shows one of the Rotax aero engine starter motors in which F.B.C. bearings are used.
FISCHER BEARINGS CO. LTD., WOLVERHAMPTON
Manufacturers of FBC and FAG bearings.
Subsidiary of British Timken Ltd.
Works: Birmingham, and Duston Northampton

higher than that of the phosphor first mentioned (viz., 75 per cent upon excitation either with 2537 A or with 3650 A) and less sensitive to temperature, whilst the absorption of blue is so slight as to be practically of no effect, so that the colour rendering is quite satisfactory. At first this phosphor was not sufficiently resistant to dissociation, but this has been remedied and excellent resistance obtained by filling the bulb of the HPL lamp with carbon dioxide instead of the nitrogen commonly used for HP lamps. The action of the carbon dioxide in this respect is to be ascribed to a little oxygen being given off which prevents a reduction from quadrivalent to divalent manganese in the phosphor. This effect can also be obtained by the direct admixture of a little oxygen to the normal nitrogen filling, but then there is a prohibitively rapid oxidation of the molybdenum leading-in strips of the discharge tube. The carbon dioxide pressure can be varied between 0·5 and 50 cm Hg, thus making it possible to adjust the thermal insulation of the discharge tube according to the starting current available. This possibility is of practical importance for the application of HPL lamps for street lighting.

INTERNAL COMBUSTION ENGINES

Possible Mechanism by which Combustion-Chamber Deposits accumulate and influence Knock

By L. F. DUMONT. (From *SAE Quarterly Transactions, U.S.A.*, Vol. 5, No. 4, October, 1951, pp. 565-576, 19 illustrations.)

THE increase in surface temperature as deposits accumulate appears to be the main factor responsible for limiting the quantity of combustion-chamber deposits formed in engines. For leaded fuels, the temperature gradient across the deposit from the surface to the metal wall and the thermal stresses accompanying this gradient eventually reach a critical value which causes deposit flaking to occur. That deposit surface temperatures increase substantially is indicated by the changes in chemical composition which occur as deposits accumulate.

It is postulated that there are three possible mechanisms by which combustion-chamber deposits could increase octane requirement: (a) volume, (b) catalysis, and (c) thermal insulation. On the basis of experiments reported herein, the increase in compression ratio caused by deposit volume accounts for approximately 20 to 40 per cent of the engine octane requirement increase, depending on the engine type and type of deposit. These particular experiments indicated that catalysis may not be a contributory factor, especially for leaded fuel deposits, although considerably more work will be required to confirm these results. The thermal insulating effect of deposits appears to be one of the major causes of deposit knocking harm.

WELDING

Welding of Aluminium Alloy Sheets by a New Method mainly intended for Automatic Operation

By G. D. NIKIFOROV. (From *Avtogennoye Delo, Russia*, No. 3, 1951, pp. 1-4, 9 illustrations.)

THE method was developed in the Soviet Union during the years 1948 to 1950 under the direction of Prof. A. A. Alov and consists in welding with an electric arc between a tungsten electrode and the material to be welded, the welding being done with the aid of a fluxing medium. The electrode is moved automatically at a constant speed enabling automatic welding. The equipment used is described in detail in this article, particularly as regards the automatic movement of the electrode. The author emphasises the importance of the welding material used insofar as the quality of the weld is concerned. Data on the current and voltage, electrode diameter, suitable height and diameter of the edges prepared for welding, welding speed and flux medium are collated in a table for various thicknesses of sheets in two different aluminium alloys. The surface quality and the macrostructure of the welds so obtained are shown by several photographs.

WIRE AND WIRE PRODUCTS

High-Strength Copper-Silver, Copper-Iron, and Copper-Iron-Chromium Wire

By W. HODGE. (From *Wire and Wire Products, U.S.A.*, Vol. 26, No. 11, November, 1951, pp. 1033-1038, 1086-1088, 7 illustrations.)

OVER a period of several years, an alloy-development program was carried out at Bettelle Memorial Institute to find new alloy compositions which could be used to produce a wire having both high tensile strength and high electrical conductivity.

This paper discusses some new copper-base alloys that have been made into wire to produce some unusual properties. The use of an insoluble metal such as iron, uniformly distributed as reinforcing fibres through the copper matrix, is an interesting new concept in wire making.

It has been demonstrated that it is possible to make copper-silver and copper-iron alloy wire in commercial plants using standard brass mill equipment. An alloy of copper-iron-chromium-magnesium has been developed which could be used for open communications wire to replace copper-clad steel in an emergency. In normal circumstances, however, there would appear to be little incentive to do so, since more copper is used than in making copper-clad steel.

A very high-strength wire composition has been indicated in the copper-iron-chromium-nickel field that could be expected to have excellent corrosion resistance, but generally uninteresting electrical properties. A wire material of high strength and fairly good electrical conductivity with unusual stability at elevated temperatures has been produced from a copper-iron-chromium-silver alloy.

A wide selection of other quaternary additions to a copper-iron-chromium base alloy showed no promise of producing wire with properties equal to those found for the three alloy compositions mentioned above.

INCREASE IN ADHESION OF SHRINK FITS BY SURFACE OXIDATION

(*Concluded from page* 15)

the information for calculating the torque required for loosening the joint and, using eq. (3), for calculating the adhesion factor γ_{tt}.

It is also clear from the graph that the sliding torque M_{st} is greater than the torque required to loosen the joint M_{tt}. This is obviously due to bonding in the joint. The value generally most important to the designer for stressing purposes is the torque required for loosening the joint or fit.

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C6

NEWS OF THE MONTH

PERSONAL

Mr. G. A. Adams has been appointed sales manager of the spring division of Geo. Salter & Co. Ltd., West Bromwich, in succession to **Mr. G. A. Beard** who has left the company to take up another position. **Mr. W. N. T. Bearder** will represent the company in Coventry and East Midlands from the area office at Warwick Road, Coventry.

Mr. Frank S. Allen, Mr. J. Corbishley, and **Mr. A. W. Martin** have been appointed directors, and **Mr. G. W. Godfrey, Mr. David Radford** and **Mr. W. M. York** have been appointed executive directors of E. K. Cole Ltd., Southend-on-Sea.

Sir Hugh Beaver has been appointed a member of the Colonial Development Corporation.

Mr. Hugh Beck, B.Sc., A.M.I.Mech.E., M.I.Mar.E., manager of the London office of Crossley Brothers Ltd., Openshaw, Manchester, has been appointed a director of the company.

Sir George Binney, D.S.O., B.A., F.R.G.S., and **Mr. K. F. Pearson** have been elected directors of the Vulcan Foundry Ltd., Newton-le-Willows, Lancashire.

Mr. F. Blackith, technical manager, **Mr. B. W. Angel,** works manager, and **Mr. C. A. Clarke,** engineer, have been appointed directors of Wellworthy Piston Rings Ltd., Lymington, Hampshire.

Mr. R. D. Brown, A.M.I.C.E., has been appointed sales manager of Richard Sutcliffe Ltd., Horbury, Wakefield.

Mr. P. Butler, B.Sc., M.I.E.E., and **Mr. W. B. Laing, M.I.E.E.,** have been appointed joint general managers of Bruce Peebles & Co. Ltd., Edinburgh.

Mr. P. G. Cladish has been appointed sales manager of Brockhouse Engineering (Southport) Ltd.

Sir Cuthbert Barwick Clegg, J.P., and **Mr. George Hardman** have been elected directors of Textile Machinery Makers Ltd., Oldham, Lancashire.

Dr. M. Cook, director of research of the Imperial Chemical Industries Ltd. (Metals Division) has been appointed joint managing director, in succession to **Mr. A. M. Kempson,** who has retired after 44 years of service. **Mr. St. J. Elstub** and **Mr. G. A. D. Smith** have been appointed directors.

Mr. A. R. Cooper, A.M.I.E.E., M.Inst.F., has been appointed controller of the North-Western Generation Division of the British Electricity Authority.

Comdr. (E.) Samuel Dickinson, O.B.E., R.N., M.I.Mech.E., has been appointed head of the Department of Engineering at the College of Art, Science and Technology, Ibadan, Nigeria.

Mr. P. D. Doulton, M.I.Mech.E., has been elected a member of the Executive Committee of the Council of British Manufacturers of Petroleum Equipment.

Mr. C. A. Foat has been appointed a director of the Ozalid Company Ltd., 62 London Wall, London, E.C.2.

Mr. J. Holden Fraser, A.M.I.C.E., has been appointed chief officer, engineering (signal and telecommunications), and **Mr. W. J. Garrod,** assistant to executive officer (mineral traffic) at the Headquarters of The Railway Executive, London.

Mr. J. K. Gilchrist, B.Sc., (Glas.), A.R.T.C., A.I.M., has relinquished his position in the research department of Babcock & Wilcox Ltd., to take up an appointment as lecturer in metallurgy and chemistry at Paisley Technical College.

Mr. Kenneth Gordon, C.B.E., M.C., has been appointed deputy managing director of Head Wrightson Processes Ltd., Teesdale House, 24-26 Baltic Street, London, E.C.1.

Mr. B. C. Gotelee has been appointed joint managing director of the Expert Tool and Case Hardening Co. Ltd., with **Mr. Ivor Lloyd. Mr. Harold Cherry** has been elected to the Board.

Mr. J. Sidney Hampton, director of Davy and United Roll Foundry Ltd., Billingham, Co. Durham, has been appointed to the additional post of general manager of the company.

Mr. W. Norman Hart, assistant managing director of Kerry's (Great Britain) Ltd., Warton Road, Stratford, London, E.15, has been appointed managing director of the Kerry's Group of Companies, in succession to **Mr. Walter Hart** who retired on December 31st, but is retaining his seat on the Board.

Mr. David Higgs, B.Sc., has been appointed a director of Higgs Motors Ltd., Witton, Birmingham.

Mr. D. J. Hopley has been appointed managing director of Oldham & Son (India) Ltd., in succession to **Mr. Edgar Oldham** who is returning to England to continue his work as chief technical officer of the overseas control division of the parent company, Oldham & Son Ltd., Denton, Manchester.

Mr. J. Howden Hume, managing director of James Howden & Co. Ltd., Glasgow, has been elected President of the Scottish Engineering Employers' Association.

Mr. J. K. Ingram and **Mr. W. J. Chadder, M.I.Chem.E., M.Inst.Gas E.,** have been elected directors of the Woodall-Duckham Vertical Retort and Oven Construction Co. (1920) Ltd., 63-67 Brompton Road, London, S.W.3.

Mr. C. Jackson, M.I.Struct.E., 243 Elizabeth Street, Sydney, N.S.W., has been appointed resident director in Australia for S. S. Lynn Ltd., Birmingham.

Mr. Alonzo Limb has been appointed sole managing director of C. C. Wakefield & Co. Ltd., 46 Grosvenor Street, London, W.1. Previously he had shared responsibility of this post with Mr. W. H. Senneck, who has now retired after 45 years of service, but retains his seat on the Board. **Mr. W. F. List** and **Mr. L. M. Broadway** have been appointed assistant managing directors.

Mr. C. W. Marshall, B.Sc.(Eng.), M.I.E.E., deputy chief engineer (research), British Electricity Authority, has been appointed controller of the South West Scotland Generation Division.

Mr. E. W. Marvill, M.B.E., has been promoted to general works superintendent, and **Mr. H. B. Harris, B.E.M.,** has been appointed production manager of F. Perkins Ltd., Peterborough.

Mr. Bertram Nelson has been elected a member of the Mersey Docks and Harbour Board.

Mr. John R. Ratcliff, B.Sc.(Eng.), M.I.Mech.E., M.I.P.E., of K & L Steelfounders & Engineers Ltd., has been elected to the Board as engineering works director.

Mr. P. R. Scutt, director of production of Tecalemit Ltd., has been appointed director and general manager of the company.

Mr. Robert Shearer, A.M.I.Mech.E., has been appointed mechanical engineer to the Clyde Navigation Trust, Glasgow.

Colonel H. C. Smith, C.B.E., D.L., M.I.C.E., M.Inst.Gas.E., has been appointed chairman of the Gas Council, 1 Grosvenor Place, London, S.W.1, in succession to **Sir Edgar Sylvester, K.B.E.**

Mr. G. J. Stedman, B.Sc.(Eng.)(Lond.), A.M.I.Mech.E., A.M.I.E.E., has been appointed generation engineer in the City Electricity Department, Bulawayo, Southern Rhodesia.

Mr. T. H. Summerson, chairman and joint managing director of Thomas Summerson & Sons Ltd., Darlington, has been elected chairman of the British Steel Founders' Association.

Mr. A. B. Waring has been elected chairman of Joseph Lucas Ltd., Birmingham, in succession to **Sir Peter Bennett.** The name of the company will be changed to Joseph Lucas (Industries) Ltd.

In thirty years and more we have designed and made a lot of springs—good springs from the best materials available. Now we feel we really have springs at our finger tips, and there isn't much we don't know about them. Don't you think all that experience would be useful to you? Established 1919. *A.I.D. Approved.*

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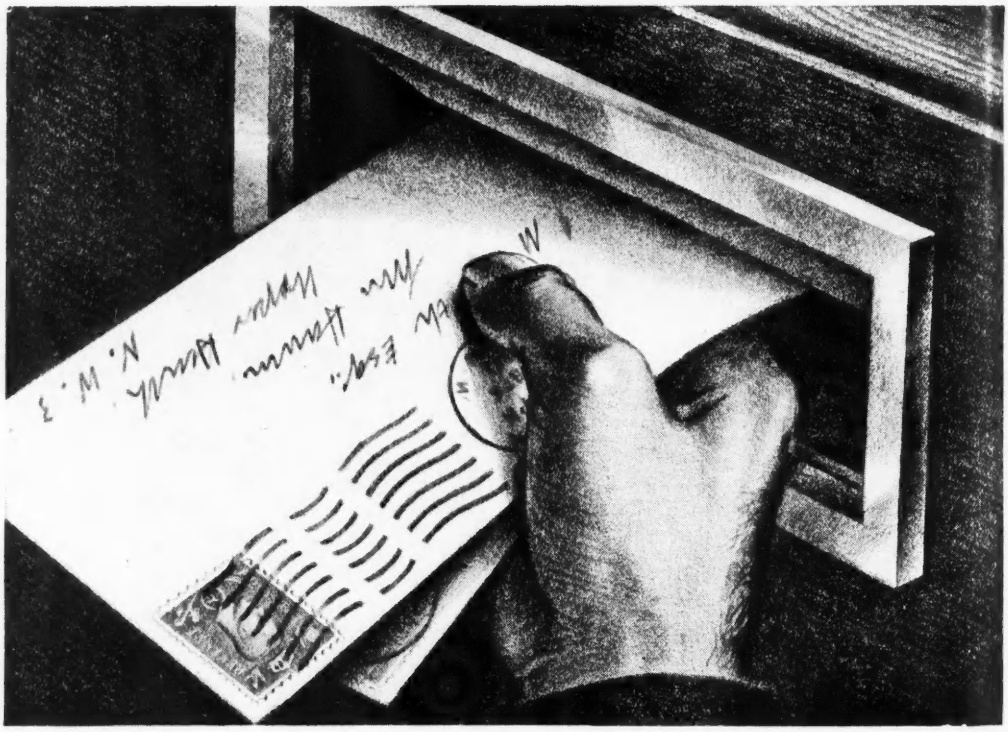

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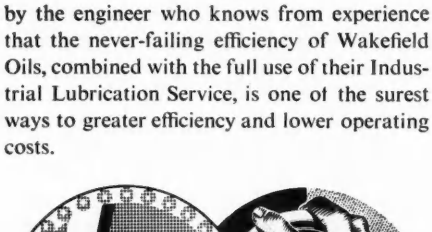

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Mr. R. G. Wingerter has been appointed assistant general manager, and **Mr. J. R. Splitstone,** district manager, of the automotive sales division of The Timken Roller Bearing Company, 3107 West Grand Boulevard, Detroit 2, Michigan.

Mr. D. S. Woodley, A.M.I.Mech.E., M.I.H.V.E., deputy chairman and technical director of Keith Blackman Ltd., Mill Mead Road, Tottenham, London, N.17., has been appointed joint managing director to share the increased duties developing upon the present managing director, Mr. Montague Burningham. **Mr. S. E. Nelson, B.A.(Cantab.)** has been appointed chief engineer of the company.

Air-Commodore W. Wynter-Morgan, C.B., C.B.E., M.C., has joined the staff of Sir W. G. Armstrong Whitworth Aircraft Co. Ltd.

BUSINESS NOTES

Coventry Gauge & Tool Co. Ltd., Coventry, has published a profoundly illustrated 1952 Calendar which is available to readers of this journal on application to the Publicity Manager of the company.

The Sir Alfred Herbert Paper. The first of the official Papers of The Institution of Production Engineers, named in honour of a Past President and distinguished member of the Institution, will be presented at the Royal Empire Society, London, on Wednesday, 19th March, 1952. It will be presented by Mr. F. H. Rolt, O.B.E., Superintendent of the Metrology Division of the National Physical Laboratory on the subject " The Development of Engineering Metrology."

Uni-Tubes Ltd. announce that they have moved to their larger factory at Alpha Works, Alpha Street, Slough, Bucks. Telephone : Slough 24606.

Standard Telephones and Cables Ltd. announce that the London sales office and warehouse of their Rubber and Plastic Cables Division has been transferred to new premises at 48 North Row London, W.1. Telephone : MAYfair 4392.

Tufnol Ltd. announce the removal of their Midland Area Sales Office to larger and more convenient premises. The new address is Cornwall Buildings, 45 Newhall Street, Birmingham 3. Telephone No. Central 5651.

The Commercial Relations and Exports Department (Industries Branch) of the Board of Trade has moved from Thames House North, Millbank, to Horse Guards Avenue, London, S.W.1.

COAL-MINING IN THE U.S.A.

(*Concluded from page* 5)

calls to mind the great physical advantages enjoyed in America. Reserves are regarded as inexhaustible, workings are shallow, seams thick and relatively free from faults. At one pit, the Team travelled underground for six miles on a level roadway driven in solid coal, undisturbed by faults or dislocation of any kind. Differences of natural conditions, they point out, make it impossible to attain in Britain the high average output achieved in America, even if all other factors were equal.

The Team found little to learn in America as far as the fundamentals of mining are concerned. Many of their observations served only to endorse policies and practices already adopted in Britain, though they did find much to emulate in the energy and ingenuity of American engineers. The extensive use of locomotives in American coal mines was a special subject of study by the Team. At one pit, the largest in the U.S.A., no fewer than 126 were in use underground. Electric trolley locomotives are accepted as unquestionably the most economical method of transport, especially in regard to man-power, and the Team recommends their introduction in Britain where conditions allow.

Many American mines have large, well-equipped workshops underground, and most of the pit machinery is overhauled there. Spare parts and sub-assemblies are also kept near the underground workshops, and in one pit, a spare loader boom, for example, was kept mounted on a special wheeled carriage ready to be coupled instantly to a locomotive. The differences in the natural conditions in the two industries made it impossible for the Team to reach any detailed conclusions after comparing safety standards and practices in the two countries.

The Report concludes with a brief consideration of the future of the American coal industry. Though unable to go deeply into the organisation of research and development, the Team was impressed with the sense of urgency and of widening scope, and found the freedom of exchange of ideas in a highly competitive atmosphere especially noteworthy. All the manufacturers of mining equipment have large development departments, and one was understood to be acquiring its own mine for experimental purposes.

Under the stimulus of competition from other fuels and of the increasingly stringent specifications of consumers, the American industry is concerning itself more and more with the efficiency with which coal is used. The tendency is, in fact, towards regarding coal almost as an ore : Though it is hoped to avoid excessive degradation, the state in which it reaches the surface will be of less importance than bulk and continuity of flow.

In place of competition from oil and natural gas, the British coal industry has to compete with constantly increasing demands for energy from steadily deteriorating reserves. A determined effort, the report concludes, should be made to develop revolutionary means, suited to British conditions, of getting coal cheaply to the surface and there turning it into the form in which full use can be made of it. The campaign to improve fuel efficiency should be intensified and allied with one to secure the full exploitation of coal as a raw material.

The College of Technology and Commerce, The Newarke, Leicester, will shortly open a new library for students (full-time, part-time and evening) in all branches of Engineering in a separate building. The Librarian wishes to provide a comprehensive collection of trade catalogues, instruction handbooks and house journals for use in this library. Such material will be greatly appreciated and should be addressed to the Chief Librarian, College of Technology and Commerce, Lero Buildings, Painter Street, Leicester.

Small & Parkes Ltd., Hendham Vale Works, Manchester 9, announce that as from January 23rd their new address for Southampton will be 5/9 Payne's Road, Freemantle. Telephone No. 71276. Service will be facilitated by new equipment, in addition to the transfer of plant, stocks, etc. from the old address at 69 Stafford Road.

The Gauge and Tool Makers' Association has prepared a model Agreement for the Engagement of Sales Representatives, and copies are available at 2/6 each (post free) on application to the Association, Standbrook House, 2-5 Old Bond Street, London, W.1. Other specimen documents issued by the Association include a model Apprenticeship Indenture (price 3/6 post-free), and a model Agreement for the Employment of Overseas Agents (price 2/- post free).

NEW INDUSTRIES IN NORTHERN IRELAND

In the Northern Ireland House of Commons, the Minister of Home Affairs (for the Minister of Commerce) stated that the undertaking to be promoted in Belfast by the American firm, Behr-Manning Corporation, would be accommodated in part of an existing factory at Castlereagh, Belfast.

The premises would be adapted and extended for the Company's purposes. It was expected that the Company would enter into occupation early this year.

Of the three factories now under construction at Ballynahinch, Coleraine and Newcastle, negotiations were in progress with potential tenants.

The factory at Castlereagh recently used for the Festival of Britain was being adapted for leasing to Short Bros. and Harland Ltd. for purposes of precision engineering.

Plans were in preparation for the erection of two factories at Enniskillen and one each at Lisnaskea and Londonderry.

TWO LANGUAGES FOR THE WHOLE WORLD

General Eisenhower has sent congratulations and good wishes to a new Bi-lingual Association formed in France. The idea is that in every country throughout the world English or French shall be taught as an obligatory second language. The founders maintain that no artificial language, however apparently simple will attain the popularity of one of these two living languages.

Thirty members of the French National Assembly have formed an interparliamentary group to further the idea, and a draft law will be presented to the French parliament during the coming year.

UNITED NATIONS OF EUROPE IDEA AT 1952 PARIS INTERNATIONAL TRADE FAIR

Thirteen European countries have adopted a United Nations of Europe idea for the 1952 Paris International Trade Fair, May 17 to June 2. These countries propose to hire a large section of the Fair for a combined, official exhibit of their typical products. The countries concerned are Austria, Germany, Belgium, Bulgaria, Denmark, Hungary, Italy, Luxemburg, Norway, Netherlands, Poland, Sweden and Yugoslavia.

A NEW NICKEL CHROMIUM ALLOY

In an effort to produce an alloy with a high resistivity and a low and stable temperature coefficient, British Driver-Harris Company of Manchester advise us that they are developing a Nickel Chromium alloy which gives the following values.

Resistivity — 800 ohms per circular mil-foot

Temperature Coefficient — ± ·00002 per degree Cent. 20°-100° C

Although the manufacturers are not in production, samples are available in sizes down to ·001". As it is believed that an alloy with these properties would fulfil very useful applications, the Company invite all those interested to communicate with their Technical department.

THE THERMAL BARRIER

The man who coined the phrase " sonic barrier " in the 30's believes that, looking ahead, a new barrier in aviation will soon have to be faced—the Thermal Barrier.

He is Dr. W. F. Hilton, who, at the National Physical Laboratory in 1936, showed a graph of drag plotted against speed, which, he said indicated how, near the speed of sound, drag suddenly rose " like a barrier against the future."

Dr. Hilton, now with Armstrong Whitworth, discusses the Thermal Barrier in a paper published by the Royal Aeronautical Society. It shows how designers are having to face a new Barrier because of the heat generated by air friction at the high speeds now possible with modern powerplants.

The heat developed by any flying body—bullet, aircraft or space rocket—rises roughly in proportion to the square of its speed. For example, at 500 miles-an-hour, the rise is 25° C or 45° F. At 1,000 miles-an-hour (a speed well within sight) the rise in temperature of the aircraft will be 100° C and " therefore " says Dr. Hilton,

Failure to ensure that cutting tools are properly sharpened and that facilities are readily available for servicing them will seriously affect the smooth running of any production programme. When considering this problem, it is necessary to bear in mind not only the quantity of work to be handled, but the diversity of operations involved and thus be sure that the Cutter Grinders installed are capable of dealing with all types of work required of them. In this respect, the Cincinnati No. 2 Tool and Cutter Grinder has proved its all round excellence as an adjunct of production units where the range of work is continuous and complex. With its unique features and range of equipment, special accessories and attachments, it is a sound basis upon which to build dependable Toolroom efficiency.

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" the pilot and a few delicate instruments must be installed in a 'refrigerator.' "

In actual practice, the effects of this square-of-the-speed law have to be qualified somewhat, due to the change in temperature at height, and to aerodynamic shape. It also takes time for the heat to soak into the machine. Again, the steady decrease of air density with height reduces the temperature rise, until, 70-100 miles up, the temperature rise is negligible.

But at the practical heights of the future, the Thermal Barrier will be a real enough problem for designers of airliners—airliners which not only have to fly fast but also carry passengers. Cabins can easily become uncomfortably hot, particularly when flying in the tropics.

Present RAF jet fighters are already being fitted with a small cockpit-size refrigerator to supply cool air to the pilot in planes hotted-up by only 25° or 30° C. The unit, which weighs only 9½ lb. works quite simply. It compresses hot air from the jet engine and then lets it expand so that it cools rapidly to below the freezing point. This cool air is then circulated in the cabin at a rate of something like 10 lb of it a minute. The same kind of refrigeration unit will have to be fitted to the high-speed airliners of the future.

Looking further ahead still, designers of pilotless missiles, though not limited by the human factor, will come up against problems of the Thermal Barrier because of its effect on materials. Metal, plastics and rubbers are all affected. In working out the theoretical effects, Dr. Hilton has considered the flight of a bullet, which, at Mach 5·4, would reach a temperature of 1,500° when " steel loses all its mechanical properties and other likely materials have already done so."

No missile is likely to travel for long at this speed unless it is high enough up to escape thermal effects. But critical temperatures may be reached in parts of the plane which are already hot—especially the engine.

" Any form of engine using mechanical compression of air is likely to be limited to a Mach number between 2·0 and 3·0 while the upper limit to the use of a ram-jet engine is likely to be between 4·0 and 5·0," states Dr. Hilton.

The rocket-powered aircraft alone may be able to fly at these very high speeds, he believes, because, by carrying its own oxygen with it, the engine is independent of air, and so the only Thermal Barrier problem is the hotting-up of the outside structure.

Designers are already investigating new materials which will stand up to high temperatures and titanium is considered one of the most likely of these metals of the future, both for engines and for outside structures.

NEW ELECTRIC REFUSE COLLECTION VEHICLE

Latest addition to the range of " Manulectric " pedestrian-controlled battery-electric vehicles is a new street refuse collection truck constructed throughout in aluminium alloy.

Built by Sidney Holes Electric Vehicles, of Brighton, Sussex, the new truck has an unladen weight of well under 8 cwts (without batteries), thus falling within the legal limit for vehicles of this type, and yet provides a carrying capacity of one ton. It was designed to fill the need for a more economical and labour-saving method of street cleansing. The new system requires three men instead of the usual five. Two are employed in sweeping the refuse into heaps, and the third, following later, shovels the heap into his truck. When fully loaded, the truck is run up a ramp over a lorry and tipped.

The vehicle is controlled and steered by a single tiller. When the operator requires the vehicle to move forward he pulls the tiller and this releases the brakes and switches on the motor. To stop he pushes back on the tiller. This applies the brakes and switches off the motor. If the operator prefers to walk behind the vehicle instead of leading it, he simply turns the front wheel by the tiller through 180° and this reverses the control mechanism. He now pushes the tiller to start and pulls it to stop.

The 2 h.p. motor, which in fact develops three times its nominal horsepower in service, is fitted with a centrifugal clutch to absorb starting torque and prevent overloading. This, together with a two-stage switch and resistance—the second stage controlled by an automatic hydraulic dashpot—ensures easy starting. The motor drives the two 18″ × 4″ split rim rear wheels through helical gearing and differential. Pneumatic or solid tyres can be fitted according to preference.

The bodywork of this new vehicle, built in hard aluminium sheeting, measures 7 ft. × 4 ft. × 2 ft. and has a domed roof fitted with four sliding sections. The trucks are supplied with either side or end tipping gear of the hydraulic type. Great stability is ensured by the grouping of the battery, motor and gear boxes close to the centre of the rear axle. A further interesting point is that in view of the very low unladen weight the road tax is only £2 per annum.

The first of thes refuse collecting vehicles recently went into service and is operating successfully at Folkstone. Fitted with a 24-volt " Kathanode " high capacity traction battery, it has an operating range of approximately ten to twelve miles under full load.

AEROFOIL MARINE FANS

The motor ship *Atreus*, built by Vickers-Armstrong, is the first of a number of new vessels under construction or on order for the Blue Funnel Line, to be equipped with Aerofoil fans manufactured by Woods of Colchester Ltd.

Marine type Aerofoil fans are so designed that, with the assistance of a patent adjustable impeller, precise requirements in air delivery, pressure, sound level and dimensions can be met economically from standardised and interchangeable parts. There is not only a wide range of sizes from 6″ to 48″ diameter, but two-stage as well as single-stage fans are assembled from interchangeable parts. The driving motors are built specifically for this particular type of duty.

A limiting factor in the use of axial flow fans on ships has been successfully overcome. Hitherto this type has been generally confined to static pressures up to about 1¼″ water gauge on account of the sound level produced by high tip speeds. It has been possible for higher pressures to be developed at moderate tip speeds by the use of multi-stage fans having stationary inter-stage guide vanes, but the system is costly and does not lend itself to quantity producction from standardised components. The problem has been solved by contra-rotating two-stage fans. These have two opposite-handed impellers driven in opposite directions by two independent motors. A contra-rotating fan develops 2⅔ times the pressure of a single-stage unit of equal size and speed without proportionate increase in sound level. Alternatively it will provide a required volume and pressure at about two thirds the tip speed of a single stage fan, and is thus appreciably quieter.

This system prevents losses due to air rotation. Air leaving a single-stage impeller rotates in a helix. Its rotational movement absorbs part of the energy imparted to the air and that proportion of the energy normally serves no useful purpose. The contra-rotating Aerofoil makes use of this air rotation by feeding the delivery from one impeller into a second stage with blades designed to accept rotating air and discharge it axially.

As the air enters and leaves in an axial direction, two or more contra-rotating units may be connected together in series. Two contra-rotating fans will develop twice the pressure of one, and so on up to a limit of about 20″ water gauge.

The motor ship Atreus is equipped with four 38″ contra-rotating Aerofoils for ventilating the machinery spaces. Each moves 13,500 c.f.m. against a static pressure of 1·0″ water gauge, absorbing on 3·5 b.h.p. The total efficiency of these fans is 73%.

The fans run at 680 r.p.m. Actually the duty could have been done at a lower first cost by a 38″ single Aerofoil running at 1000 r.p.m. But Alfred Holt prefer to employ the exceptionally slow speed dual-duty type for four reasons, namely (1) reduced sound level, (2) high efficiency, (3) simplified regulation, (4) safeguard against total shut down.

The contra-rotating Aerofoil is referred to as a Dual Duty fan as it provides a simple form of volume regulation. On direct current supplies either full or two-thirds volume may be obtained when the two motors are electrically connected in series or parallel by the controller. On a.c. supplies the same result may be obtained by switching off and idling the first stage impeller. In both cases the power consumption at the lower volume is reduced to less than half maximum.

Since a dual-duty Aerofoil is driven by two independent motors it provides a safeguard against the possibility of motor failure, as failure of a motor merely means a reduction in air volume of about a third.

THE ROTARY DRAW FORMER

The Rotary Draw Former has been developed for stretch-forming Haynes-Stellite and various vanadium alloys used in the afterburners and combustion chambers of jet engines. It also can produce a number of other jet engine parts which have not been readily produced by other methods.

It consists of a power driven rotary steel table, similar to a Vertical Boring mill, and a horizontal bed on which is mounted a hydraulically movable carriage. On the carriage is mounted a swivelable ram, like a large Shaper—operated by a hydraulic cylinder and the whole element mounted on roller bearings.

On the Ram is adjustably mounted one of two Stretch Jaws. The other jaw is mounted on the rotating table and the work is stretched between them. The work previously is shaped roughly to the required cross section as are also the gripping jaws. The metal is then stretched between the jaws, and this pressure is automatically held constant during the forming operation. The table is then revolved. This causes the metal to be stretched or drawn over the outer diameters of the shape mounted upon the table, the amount of draw becoming progressively less toward the inner diameter where very little elongation may be required.

Simultaneously, and to assist the process, and to assure accuracy in cross section, a side head applies hydraulic pressure through a hard bronze shoe, wiping the metal onto the revolving die as the table revolves.

Rings up to 48″ in diameter have been drawn with a ten thousandths tolerance for variation in cross section or circumference.

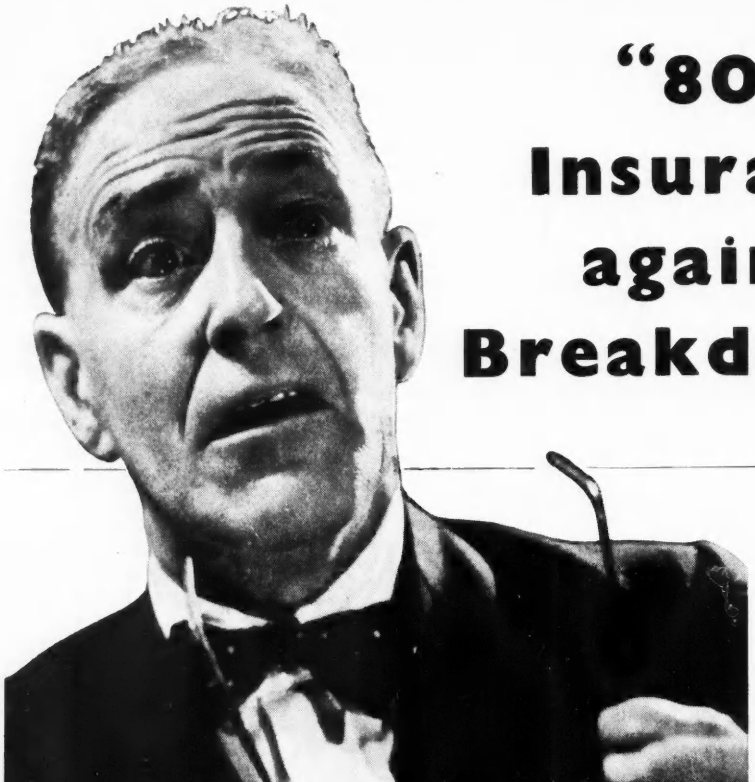
In the final operation the Rings are held in a welding fixture and automatically welded with atomic hydrogen, the cooling being so rapid that distortion in the finished ring is held to a minimum. No restretch operation is required and, indeed, in these tough metals restretching is seldom satisfactory.

The Rotary Draw Former will produce equally well elliptical or rectangular shapes. Where complete circular or closed shapes are required, the work is drawn on a spiral die and the ends are sprung together for the final welding operation.

The same machine will also produce long sweeping open curved shapes, shapes containing reverse bends, or curves in two planes. It will form aluminium or bronze, and alloy extrusions, and will vary the angularity of the extrusion, as in wing attach angles or tank straps, while forming the work. It will form round, square, or other hollow tube shapes. Sheets of all sorts and sizes can be handled by changing to suitable jaws.

It will work equally well in the toughest steels, or in very light aluminium extrusions, the latter by reason of the hydraulically balanced ram and the roller mounted stretch ram and cylinder which respond to very slight pressures or resistance.

The dies in use for rotary work consist of a turned cast iron base on which is mounted a strip of steel so shaped as to give the required cross section. This ring is either turned up to size and split, and welded in place spirally, or it is planed and one end welded to the die.



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The Rotary Draw Former ram then wipes the steel bar spirally around the cast iron base and it is so welded into position.

Dies so made cost much less to produce than press dies and will make shapes virtually unobtainable by any other means. The metal, prestretched and apllied to the die while in this condition, gives very good product in the very tough materials needed in jet engine manufacture and at a minimum cost and loss from scrap.

The Rotary Draw Formers are produced in six sizes : 12-½ ton, 25 ton, 35 ton, 50 ton, 75 ton, and 100 ton. They are on order by most American manufacturers of jet engine parts.

The Contour Former designed by Cyril J. Bath, president of the Cyril Bath Machinery Co., 6984 Machinery Street, Cleveland, Ohio, U.S.A., can be converted to a Rotary Draw Former by the addition of appropriately designed self contained supplementary parts.

THE ADMIRALTY STANDARD RANGE I ENGINE

Details of a new type of diesel engine, which is exceptionally compact and gives more power for a given weight than previous designs, can now be published.

Detailed design was undertaken by the Engineering Department of H.M. Dockyard, Chatham, in conjunction with the Admiralty Engineering Laboratory, West Drayton, and the manufacture of a prototype 16-cylinder version was commenced at Chatham at the end of 1948.

The engine was called the Admiralty Standard Range I (A.S.R.I.) engine and designs have now been completed for the 16 and 12 cylinder ' V ' and the 8 and 6 cylinder " in line " versions in both supercharged and unsupercharged forms.

Numbers of these engines are now being produced at Chatham Dockyard and various well known firms for general application in the Navy.

The general particulars of A.S.R.I. engines are

	16 V.T.S.	12 V.T.S.	8 L.T.S.	6 L.T.S.
Bore	—	9¾"	—	—
Stroke	—	10½"	—	—
Maximum R.P.M. ..	—	1,000	—	—
Maximum B.H.P. Supercharged	2,000	1,500	1,000	750
Maximum B.H.P. Unsupercharged ..	1,400	1,050	700	525
Dry weight (lb) (including engine mounted auxiliaries)	36,000	29,000	24,000	19,000
Length	16′ 10″	14′ 0″	16′ 6″	14′ 0″
Breadth	5′ 4″	5′ 4″	4′ 3″	4′ 3″
Height	8′ 7½″	8′ 6″	8′ 7″	8′ 6″

The design incorporates :

(a) direct injection, 4 valve cylinder heads ;
(b) all welded steel frame ;
(c) chromium plated cylinder liners ;
(d) copper-lead main and large end pre-finished thin shell bearings, the latter being of fork and blade type ;
(e) engine driven and engine mounted lubricating oil scavenge and pressure pumps and sea and fresh water cooling pumps ;
(f) hydraulic governors on both propulsion and generator engines.

Particular attention has been paid to complete interchangeability of all replaceable parts, including identical crankshafts and bedplates for " in line " and " V " versions of equivalent number of crank throws, and to accessibility and ease of maintenance.

New-Multi-coloured identification of Tenawire. Tenaplas Ltd., London and Nottingham, announce that they have now produced wires with 2-colour identification. This has been made possible by the development of special pigments and lacquers which are highly resistant to abrasion, light, fast and resistant to most corrosive acids and solvents.

All standard gauges of wire, both single and multi-stranded, are being produced with P.V.C. installations of all thicknesses in which the base colours of the P.V.C. with a superimposed and lacquer spiral of different colours enable colour coding. Colours can be to any specification.

Plant Maintenance Productivity Team. A specialist team on Plant Maintenance left for America on the " Queen Mary " on December 31st, to spend six weeks in the United States studying methods and techniques in the field of Plant Engineering. The terms of reference of the team are as follows :—

(a) To study the organization of American methods of industrial plant servicing and maintenance, with the object of securing maximum productivity.
(b) In particular, to study systems of planned preventive maintenance, with special reference to the statistical control used and to the degree of co-ordination between plant engineer and designer.
(c) To study American wage structures, bonus and incentive systems for maintenance work.
(d) To study safety precautions taken for maintenance personnel.

The composition of the team is as follows :—

Mr. J. R. Stevenson, M.I.Prod. E. (Team Leader), Works Director, E.M.I. Factories, Ltd., Hayes, Middx.
Mr. M. Brookes, A.M.I.Mech.E., M.I.Plant.E., Chief Engineer, Lister & Co. Limited, Bradford, Yorks.
Mr. C. E. Halter, A.M.Inst.Pet., M.I.Plant.E., Plant Engineer in Charge of Refineries, National Oil Refineries, Ltd., Llandarcy, South Wales.
Mr. T. C. Robinson, Works Engineer, Products Works, Imperial Chemical Industries, Ltd., Billingham, Co. Durham.
Mr. G. C. Allfrey, M.I.Mech.E., M.Inst.E., Director of Royal Ordnance Factories, (Engineering), Ministry of Supply, London.
Mr. F. G. Hilton, Consultant, Associated Industrial Consultants, London.
Mr. W. J. Carron, Executive Member, Amalgamated Engineering Union, London.
Mr. E. Stanley, Foreman Fitter, Reckitt & Colman, Ltd., Hull, Yorks.
Mr. Colin Troup, B.Sc.Hons., A.C.G.I., A.M.I.Mech.E., A.M.Inst.F., M.I.Plant.E., (Secretary), Editorial Director, John D. Troup, Ltd., London.

It is hoped that the Report of the team's visit will be published in the early autumn of 1952.

BRITISH STANDARDS

(*Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.*1)

Emergency Specifications for Case Hardening Steels. As a result of the present serious shortages of alloying elements for steel, the Steel (Rearmament) Panel of the Ministry of Supply has under consideration the problem of economy in the use of such elements by the replacement of specifications in which their content is relatively high by others stipulating a much lower content.

Eight specifications designated En. 351, 352, 353, 354, 355, 361, 362 and 363 covering case hardening steels, have consequently been published by the British Standards Institution in Addendum No. 1 to B.S. 970. They are intended as an emergency measure to replace the case-hardening steels En. 33, 34, 35, 36, 37, 38, 39 and 325 of B.S. 970 : 1947. Price 1/–.

Electrically Heated Pilot and Pitotstatic Pressure Heads for Aircraft. B.S. G.135 : 1951. In addition to specifying the requirements for electrically heated pitit heads, this specification deals with two grades of pitotstatic heads, i.e., suitable for use at Mach numbers up to, and greater than 0·85. Price 1/–.

Suitable for use at Mach numbers up to 0·85.

Glossary of Aeronautical Terms. B.S. 185, Pt. 3 : 1951. This is the concluding portion of the revision of the Glossary of Aeronautical Terms of which Parts 1 and 2 have already been published. It has been extended in view of recent development and includes sections on navigation, parachutes, air traffic and ground services, radiocommunication and radiolocation, and meteorology. It also contains a combined index of the terms defined in all three parts. Price 7/6.

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1. Serviron. 8-page brochure describes the properties and applications of a material which combines the qualities of protective coating, a penetrating lubricant and a moisture resisting medium. Applications include Marine Hulls, Pipe Lines, Cooling Towers, Hot Water Tanks, Air Conditioning Units, Heaters and Heating Coils, Gears, Conveyors, Chain Pulleys, Packings, Locomotive Tenders and Railway Axle Journals, Diesel Cooling Systems, etc. Simple rules for the application of this material to metal, wood or concrete surfaces, are included in the brochure.

2. Infra-red Strip Drying Equipment for every Industry. Illustrated leaflet describes the advantages of the infra-red projector which offers a heat density of up to three times that of lamps and can be varied by turning a calibrated dial. The infra-red technique can be used for industrial processing for all purposes. It can compete successfully, it is claimed, with any other form of heating or drying, particularly in thermal efficiency and performance.

3. Furnace Safety Systems. Illustrated leaflet presents details of fully electronic equipment for gas and oil burning installations, e.g., kilns, water and air heaters, boilers, steam generators, cereal drying and heat treating ovens. The equipment provides flame failure protection for fully or semi-automatic gas and oil burners, both on initial lighting up, and during normal operation.

4. Portable Gas Furnaces. Illustrated leaflet contains complete specifications of a series of portable gas furnaces manufactured in eight standard sizes. Typical output and cost figures are given. Advantages include long life, low maintenance, cool conditions, constant heats and efficient combustion which results in negligible scaling.

5. Base Exchange Water Softeners and Ion Exchange Equipment. Well designed and profoundly illustrated 20-page booklet deals with the principles and applications of manually controlled, semi-automatic and fully automatic Base Exchange Water Softeners. Illustrations include multi-coloured equations to show the reactions involved in hydrogen ion exchange, and in water demineralising. Water Softeners and Water Treatment Plants are described and illustrated.

6. Problems of Motor Vehicle Suspension. This 24-page booklet presents some of the more outstanding problems of motor vehicle suspension and offers comments which will be of assistance to all who are concerned with these problems in their professional capacity.

7. Boiler Scaling and Tube Cleaning. Reprint of an illustrated article describing a simple and inexpensive apparatus for de-scaling boilers, economiser tubes and pipes.

8. Anti-Vibration Mountings and Mechanical Rubber Products. Profoundly illustrated 8-page brochure dealing with a large range of rubber to metal bonded components for stationary and mobile engines, motors and machinery. Specifications of shear and compression type standard mountings are included in the brochure. Special designs to meet individual problems are offered. Anti-vibration devices can be designed to control and insulate vibration travelling in several directions.

9. The Modern Method of Rust Prevention. 20-page booklet just issued describes and demonstrates the advantages of Vapour Phase Inhibitor, developed in the research laboratories of the Royal Dutch-Shell Group of Companies. Used in form of a coated paper, it is the most complete and simplest means of eliminating corrosion.

Used primarily for protective packaging of articles made of bare steel or aluminium, the V.P.I. wrap is also widely used for plated and coated steel, and, particularly for machine tools, aircraft and motor car parts, gauges and instruments, electrical apparatus, moulds for rubber and plastic, scientific apparatus, etc. The booklet is richly illustrated and offers complete particulars on the use of this valuable packaging material.

10. Revolving Field Alternators. 16-page brochure, very nicely produced and illustrated, describes alternators of the revolving field type salient pole pattern. They are suitable for engine drives of various types or, alternatively, can be driven by electric motors when alternators of non-standard voltage and frequency are required. Many of the excellent illustrations show alternators installed in power stations and industrial undertakings. The brochure gives details of the construction of standard alternator sets. Specifications are given in additional dimension leaflets.

11. Radiant Heating at its Best. Illustrated folder just published, introduces the "Thermoflectors," a new system of Factory Heating. The system retains the advantages of heating systems using overhead pipes carrying steam or water at relatively high temperatures and achieves a saving of approximately 20% in convection losses to the roof space. The principle underlying this development is explained, and a diagram shows the measured results of heating with plain pipes with and without reflectors.

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SITUATIONS VACANT

BRITISH ELECTRICITY AUTHORITY NORTH EASTERN DIVISION

APPOINTMENT OF SENIOR ASSISTANT ENGINEER GENERATION (OPERATION) DEPT.

Applications are invited for the appointment of Senior Assistant Engineer in the Generation (Operation) Department at Divisional Headquarters, Newcastle upon Tyne.

The successful candidate will be required to take charge of a section responsible for co-ordinating the work of specialists both on the mechanical engineering and economical aspects of Power Station Operation.

Applicants should have good technical qualifications and practical experience in investigational and project work though this need not necessarily have been in power stations.

The salary for this appointment will be in accordance with the National Joint Board Agreement, Garde 1, Schedule 'C' (£945-£1,141 per annum) and will commence at a point commensurate with qualifications and experience.

Superannuation will be in accordance with the British Electricity Authority and Area Boards Superannuation Scheme.

Forms of application may be obtained from the Divisional Establishments Officer, British Electricity Authority, North Eastern Division, Carliol House, Newcastle upon Tyne, 1, to whom they should be returned to arrive not later than 31st January, 1952.

DESIGNER DRAUGHTSMEN REQUIRED for interesting work on Gas Turbine Aero Engine Test Equipment. The work covers the design and detail of equipment for research, experimental and production projects from initial engine build procedure to component testing and final testing. Salaries in excess of £550 per annum will be considered for applicants capable of working on own initiative. Expenses paid to interview. Apply to reference DD1, **Personnel Manager, Armstrong Siddeley Motors Limited,** Coventry.

ARMSTRONG SIDDELEY MOTORS have vacancies in their Coventry factory for Senior and Intermediate Jig and Tool Draughtsmen to work on both the gas turbine aero engine and car production. This is work of national importance and the right men will be suitably rewarded. Please reply in some detail to Reference JTD, **Armstrong Siddeley Motors,** Coventry.

DESIGN AND DEVELOPMENT ENGINEERS are required by the English Electric Co. Ltd., for their Gas Turbine Department at Rugby. Applicants should have a Higher National Certificate or a Degree coupled with a practical engineering background preferably directly concerned with gas turbines. Please write giving full details of qualifications and experience, and quoting ref. 345B, to **Central Personnel Services, English Electric Co. Ltd.,** 24/30 Gillingham Street, London, S.W.1

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WANTED.—Back Issues of THE ENGINEERS' DIGEST, Vol. XII, Nos. 2 and 5 (February and May, 1951) at the full price of 3/6 per copy. We also should like to re-purchase complete volumes for 1940 and 1941 at the original subscription price. **Subscription Department, "The Engineers' Digest,"** 120 Wigmore Street, London, W.1.